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STUDIES IN THE GENUS BIDENS. V

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 269

EARL E. SHERFF

(WITH PLATES XI–XIV)

Bidens exigua, sp. nov. (pl. XI).—Herba annua, 1.5–3 dm. alta; caule tenuissimo, subrecto, striato, subsimplici. Folia opposita (summa alternata), membranacea, petiolata, petiolo adjecto 3–5 cm. longa, bipinnata, glabra; foliolis (3 aut 5) maximam partem 3–5-partitis; lobis integris, subobtusis, infirme apiculatis. Petioli 0.5–2 cm. longi, basi connati. Capitula pauca aut solitaria, discoidea, tenuiter pedunculata pedunculis 2–5 cm. longis, ad anthesin 5–6 mm. longa et 1.5–2 mm. lata infra, 2–3 mm. lata supra; in fructu, circ. 9 mm. longa et 2–5 mm. lata. Involucrum basi sparsim hispidum aut glabratum; bracteis duplici serie dispositis; exterioribus (4–7) linearibus, 2–3 mm. longis, ciliatis, ad faciem glabris aut pubescentibus, ad apicem induratis; interioribus dimidio longioribus, glabratis, lanceolatis, striatis, margine diaphanis. Achaenia (submatura) linearia, glabra aut supra ad margines remote hispida, bi- aut triaristata aristis retrorsum hamosis hamis tenuibus, 4–8 mm. longa.

SPECIMENS EXAMINED.—*C. H. T. Townsend* 1513, alt. 1607 m., Chosica Canyon, Peru, April 20, 1913 (Herb. U.S. Nat. Mus., no. 602943, type).

The plants of the type sheet would seem at first to be merely depauperate or impoverished forms of some species normally larger and perhaps already described. The technical characters, however, do not match those of any other species known to me. There are several species very close to *B. exigua* all of

which might once easily have passed for *B. bipinnata* L., yet which, with subsequent advances in our knowledge, have been proved indisputably to be distinct and severally valid. Among these are *B. heterosperma* Gray and *B. Lemmoni* Gray of the southwestern United States and Mexico, and *B. parviflora* Willd. of Asia. *B. exigua* is nearest to *B. Lemmoni* and *B. parviflora;* like these, it may well be expected to prove constant and worthy of specific rank.

Bidens duranginensis, sp. nov. (pl. XI).—Herba annua, glabrata, demum circa 6–9 dm. alta; caule subtetragono, ramis acute tetragonis, ramis acute tetragonis, longis et tenuibus, striatis, infra minute pubescentibus. Folia opposita, petiolata, petiolo adjecto 10–12 cm. longa (eis ramorum 1–3 cm. longis), pinnata, serrata aut dentata (aut etiam inciso-dentata), ciliata, foliolis ovatis aut ovato-lanceolatis, saepe duobus aut quatuor imis cuiusque folii tripartitis. Petioli (foliorum caulis) 2.5–4 cm. longi, ad basim ciliati et connati. Capitula multa, subligulata, tenuiter pedunculata, pedunculis 3–8 cm. longis, ad anthesin 4–7 mm. alta et (ligulis adjectis) 0.8–1.3 cm. lata, in fructu 1.2–1.4 cm. alta et 6–8 mm. lata. Involucrum basi hispidum, bracteis duplici serie dispositis; exterioribus (circ. 8) linearibus, fere glabris, apice induratis, 2–3 mm. longis; interioribus dimidio longioribus, anguste lanceolatis; membranaceis, margine diaphanis. Ligulae (3–6) subalbidae, anguste ovatae, 4–7-striatae, 4–6 mm. longae. Achaenia linearia, nigra, glabra aut supra sparsim hispida, 2–4-aristata aristis flavis et retrorsum hamosis, corpore 6–12 mm longa.

SPECIMENS EXAMINED.—*Dr. Edward Palmer* 756, west side of Iron Mountain, vicinity of city of Durango, Durango, Mexico, October 1896 (Herb. Gray, type; Herb. Field Mus., no. 51825; Herb. U.S. Nat. Mus.); *idem* 612, vicinity of city of Durango, Durango, Mexico, April to November 1896 (Herb. Field Mus., nos. 51704 and 51705; Herb. Gray, differing from type material, apparently, merely in being somewhat younger).

This species, if we attempt to delimit it in a taxonomic way, is confessedly of unsatisfactory status. The type collection had been determined as *Bidens anthriscoides* DC., but the plants are very different from the type material of that species (*Berlandier* 1010, Herb. Brit. Mus.; Herb. Drake, Paris). It is manifestly an ally of *B. pilosa* L., from which it differs in its whitish rays and in its foliage, the lower leaflets of the stem leaves tending to be distinctly tripartite. This last character distinguishes it likewise from *B. leucantha* (L.) Willd. In foliage characters it slightly simulates *B. chinensis* (L.) Willd. of

the Orient and *B. subalternans* DC. of South America. I have seen two specimens by E. O. WOOTON from New Mexico (Mesilla Valley, Dona Ana County, October 1895, U.S. Nat. Herb., nos. 561445 and 663170; referred to *B. anthriscoides* DC. by WOOTON and STANDLEY, Contrib. U.S. Nat. Herb. **19**:704. 1915) that are evidently true *B. bipinnata* L., yet which approach *B. subalternans* DC. A third plant, also by WOOTON (Las Cruces, New Mexico, October 1895, Herb. N.Y. Bot. Gard.), approaches *B. subalternans* DC. in foliage still more, but is nevertheless clearly a form of *B. bipinnata* L. All three of these plants are suggested by the type of *B. duranginensis*. They appear, however, to be entirely distinct in a specific way. Future field studies, to determine the range of variation and the limits of demarcation for the Durango plants, are highly desirable.

No other group in the genus *Bidens* has been so badly neglected heretofore, considering the number of species involved, as has that group native to the Hawaiian Islands and other islands of the Pacific, and, by some authors, segregated as a separate genus, *Campylotheca*. Nearly a century ago GAUDICHAUD (Voy. Freycinet Bot. 464. *pl. 85*. 1826–1829), describing a species collected in the Hawaiian Islands during FREYCINET'S voyage, named the plant *Bidens micrantha*. Shortly afterward CASSINI (Dict. Sci. Nat. **51**:475. 1827) called attention to the curved achenes of GAUDICHAUD'S species. He made this achenial character the basis for proposing his new genus *Campylotheca*. Later LESSING (Linnaea **6**:508. 1831) accepted CASSINI'S genus for species like *Bidens micrantha* Gaud., but he erected a new genus, *Adenolepis*, to include a somewhat different form. I propose to discuss *Adenolepis* in a future article. Concerning *Campylotheca*, however, we may proceed to note that the name was retained by DE CANDOLLE in his *Prodromus* (**5**:593. 1836), although elsewhere it was accorded only slight attention. In fact, the collections in those days embraced so few specimens from the Pacific Islands that little study was made of the Pacific flora by taxonomists. NUTTALL, in 1841 (Trans. Amer. Phil. Soc. N.S. **7**:368), reduced *Campylotheca* to the rank of a section under *Bidens*, but did not give extended reasons for so doing. His attention had been directed to the subject by his having traveled among the Hawaiian Islands and discovered there at least one new species of *Bidens* (*B. gracilis*). NUTTALL, however, did evince a rejection of CASSINI'S main character for *Campylotheca*,

namely, the curved or twisted achenes. He worded his description to read "sometimes curved or contorted," and for one species (*B. mutica*) he definitely described the achenes as "straight." Since NUTTALL's time, we may add, many other closely affiliated species have been discovered, including forms of *Bidens micrantha* itself, which have straight achenes, thus bringing the curved-achene character into discredit. In 1856 SCHULTZ BIPONTINUS undertook the determination of various specimens collected on Nukahiva by EDWARD JARDIN. Finding four new species native to this single small island, SCHULTZ BIPONTINUS appears to have entered upon a very careful and painstaking research into the subject of their generic affinities, finally publishing his results[1] (Flora **39**:357. 1856). As regards the maintenance of a genus *Campylotheca* apart from *Bidens*, he was unreservedly against such a course. His four new species from Nukahiva and all of the Hawaiian species he referred to *Bidens*.

In my own attempts accurately to evaluate SCHULTZ BIPONTINUS' opinion, I sought four years ago to repeat his studies upon the Nukahiva species. Through the generous assistance of M. ST. AHNNE, President of the Chamber of Agriculture of Tahiti, and the careful, persistent search by his friend, M. HENRY, President of the French Alliance of Nukahiva,[2] I have been able to secure many mature achenes and herbarium specimens from the same island where JARDIN originally collected. Achenes of each kind were planted, and thus, during a period of three years, several hundred live plants have been obtained for observation. Having supplemented in this way my examination of the few herbarium specimens available, I have been able to match all of SCHULTZ BIPONTINUS' four descriptions very well. The four species (*Bidens cordifolia*, *B. polycephala*, *B. serrulata*, *B. Jardinii*) are clearly distinct in leaf characters of the older plants and in fruit characters. More-

[1] For a personal estimate, apparently unbiased and accurate, of the taxonomic ability and sagacity that SCHULTZ BIPONTINUS displayed at times, see BENTHAM, Jour. Linn. Soc. **13**:340. 1873.

[2] I cannot too gratefully thank M. ST. AHNNE and M. HENRY for their great kindness shown to me during the progress of my work. Repeatedly they have assisted in procuring for me the very materials that were essential for a correct understanding of the far away Pacific Island flora.

over, none of the four is found to differ generically from the various Hawaiian species, both groups even emitting the same peculiar carrot-like odor when the leaves are bruised. There can remain no doubt, therefore, regarding the exact basis of SCHULTZ BIPONTINUS' study. Furthermore, the scholarly and critical way in which he attacked the entire subject must needs inspire a strong sense of confidence in his judgment and in the course pursued by him in equating *Campylotheca* with *Bidens*.

In 1861 ASA GRAY (Proc. Amer. Acad. **5**:125–128) made the next important contribution to a knowledge of the group. GRAY had received from the Museum of Natural History in Paris several specimens collected by M. J. REMY in the Hawaiian Islands, also a number from the United States Exploring Expedition under Captain WILKES, collected in the Hawaiian Islands, Tahiti, Eimeo, and elsewhere in the Pacific. Most of these were new species. GRAY'S publication indicates that he was probably unaware of SCHULTZ BIPONTINUS' paper. Thus, for example, he inadvertently created the name *Coreopsis Macraei* for a plant already named by the latter *Bidens Campylotheca*. As, therefore, he does not seem to have read SCHULTZ BIPONTINUS' paper, it is all the more interesting and valuable to find that GRAY, too, was compelled to abandon the name *Campylotheca*. Species having the achenes wingless and the awns retrorsely barbed he described under *Bidens*. But several other species, different in having either exaristate achenes or even winged achenes, he described under *Coreopsis*. Thus he described *Bidens hawaiensis*, *B. lantanoides*, *Coreopsis mauiensis*, *C. macrocarpa*, *C. Macraei*, *C. cosmoides*, and *C. Menziesii*. GRAY'S own words at the time of describing some of these species are worthy of note. Speaking of the futility of maintaining *Campylotheca* as a separate genus, apart from *Bidens* and *Coreopsis*, he said: "Its adoption merely gives us three limitless genera unmarked by any peculiarity in habit, in the place of two artificially separated ones. . . . . Vain is the attempt to draw absolute limits where Nature luxuriates in gradations" (Proc. Amer. Acad. **5**:126. 1862).

In 1888 there appeared the posthumous *Flora of the Hawaiian Islands* by WILLIAM HILLEBRAND. HILLEBRAND, from his twenty years of resident study in the Hawaiian Islands and his careful

investigations subsequently, was eminently well versed in their species. His treatment assumes almost the aspect of a monographic revision, and it is evident that he possessed much more than an ordinary knowledge of *Bidens* and related groups. His brilliancy, however, appears to have been manifested, as is so apt to occur with a local botanist, less in the excellence of his genus concept than in that of his species concept. And, even in the latter respect, his generalizations are often necessarily faulty because of the inadequacy of his material. HILLEBRAND, like GRAY, appears never to have seen SCHULTZ BIPONTINUS' paper. He discarded GRAY'S treatment, however, and adopted once again CASSINI'S name *Campylotheca*. Speaking of *Campylotheca* he says (p. 211): "The genus, as it presents itself now, stands evidently nearer to *Bidens* than to *Coreopsis*, and might be merged in the former if it were not for the winged achenes of so many species,[3] which, if admitted in the character of *Bidens*, would efface the limits between that genus and *Coreopsis*." GRAY'S Hawaiian *Bidens* is transferred by HILLEBRAND to *Campylotheca*.

This effort to break down the genus *Bidens* into smaller units is not the first of its kind. As early as 1790,[4] NECKER (Elem. Bot. 1:86–87) subdivided the genus into two new genera. For these he proposed the names *Pluridens* and *Edwarsia;* the first group to include those species with simple foliage (for example, *Bidens cernua* L.), the second to include those species with foliage dissected (for example, *B. pilosa* L. and *B. pinnata* L.). In 1794, MOENCH (Meth. 569 and 595) followed NECKER'S treatment essentially, but substituted the names *Bidens* and *Kerneria* for NECKER'S two names. Neither NECKER'S treatment nor that of MOENCH is today accepted by botanists. In 1836, DE CANDOLLE (Prodr. 5:633) described a new plant that resembled *Bidens*, but which appeared remarkable in having the ligules pistillate and fertile. DE CANDOLLE created the genus *Delucia* therefor, and his new plant he named *Delucia ostruthioides*. Later SCHULTZ BIPONTINUS (Seem. Bot. Voy. Herald 308. 1852–1857) renamed the species *Bidens ostruthioides*, and this latter name has been widely accepted

[3] Regarding the inaccuracy of this statement, cf. footnote 8.

[4] Cf. E. L. GREENE, Pittonia 4:245. 1901.

ever since.[5] In 1901, GREENE (Pittonia 4:242–270) presented the results of a study of *Bidens*. He commented upon the dissimilarity between such species as *B. cernua* L. and *B. tripartita* L. Even so radical a botanist as he, however, refrained from proposing a generic segregation of the *B. cernua* forms. Nevertheless, GREENE did segregate the aquatic *Bidens Beckii* as the type of a new genus, *Megalodonta;* and, when the peculiar achenes of this species are considered, it seems wise to accept GREENE's new genus as valid.

Strangely enough, no one appears to have tried to segregate generically the pronounced and well defined group of *Bidens* species typified by the species *Bidens reptans* (L.) G. Don.[6] These species differ from the more typical species in being climbers, and in having long flat achenes that are hispid along the two edges in such a way at times as to suggest a centipede. Again, my own *Bidens mirabilis* (BOT. GAZ. 61:496. *pl. 31.* 1916), with achenes flat, strongly constricted above into a thick neck and crowned with even 8–10 aristae, might be segregated as the type of a new genus. Similarly, the anomalous *Bidens clarendonensis* Britton, with trailing, somewhat woody stem, and thick, rhombic-ovate leaves, would be interpreted by some as representing a new genus.

Thus it is seen that, if we accept the narrow concept of *Bidens* held by CASSINI, LESSING, and HILLEBRAND, and seek to segregate the native Pacific species under the name *Campylotheca*, to be consistent we shall have to subject the entire genus *Bidens* to a process of subdivision and segregation, resulting in some six or eight genera. There are at least two good reasons for not adopting such a course. In the first place, the accuracy of such a series of interpretations is not so well established as to justify overturning almost the entire nomenclature of the genus. In the second place, the lines of demarcation among the various subordinate groups are

[5] In the herbaria *Bidens ostruthioides* is the universally used name. It is interesting to note that a closely similar form was described by KLATTE as *Bidens guatemalensis* (Bot. Jahrb. 8:44. 1887). Another related form, apparently more clearly distinct, however, was placed by BENTHAM in *Bidens* and described as *B. costaricensis* (Benth. ex Oerst., Kjoeb. Vidensk. Meddel. 94. 1852).

[6] DE CANDOLLE (Prodr. 5:599. 1836), however, did create the name *Bidens Coreopsidis* for one of these species. And, even earlier, the names *Coreopsis reptans* L., *Coreopsis incisa* Ker., etc., had been given to certain of these species, but without very serious consideration being given to their generic affiliations.

so fluctuating and inconstant that efforts to apply a binomial system of nomenclature to the many species would be rendered even much more difficult than before. I am constrained to reject, therefore, any idea of seriously interfering with the general status of *Bidens*. CASSINI's name *Campylotheca* I am compelled to discard.[7]

Having laid aside the name *Campylotheca*, there remains one further matter with which to deal. As stated previously (BOT. GAZ. **59**:308. 1915), we find among the numerous species of *Bidens* and the allied genus *Coreopsis* "no absolute uniformity in even one distinctive character. However, one such character does persist to a surprising extent. It is the presence (in *Coreopsis*) or absence (in *Bidens*) of two lateral wings upon the mature achene. Among so many species from widely remote regions does this character separate two genera with different aspects that, *in cases where other criteria are absent*, it appears to offer the only logical basis of distinction." This presence or absence of achene wings was given great weight by GRAY, but in the Pacific flora the wing character is unreliable, and will lead, if absence of wings be demanded from all species of *Bidens*, to an arbitrary and unnatural arrangement. Some three or four Hawaiian forms commonly have accessory awns or barbs below the achene's apex, and either these or the principal awns frequently are decurrent along the achenial edges as a more or less thickened margin or even as a wing; or at times the awns seem unrelated to the wings. In "*Coreopsis mauiensis*" Gray, these wings are very conspicuous. The number of Hawaiian

[7] In taking this step it is reassuring to read the words of so eminent a student of the Compositae as BENTHAM. Speaking of CASSINI and his work, he stated (Jour. Linn. Soc. **13**:338. 1873): "Unfortunately, however, in working out the details of the genera in the 'Dictionnaire,' he indulged in an enormous and useless multiplication of generic names, which only tended to throw the nomenclature into confusion, and cast a slur upon all his labors. Wherever he observed a slight difference in the involucre, pappus, or general aspect, or could not readily identify an imperfect specimen, an engraved figure, or a description often incorrect, he at once set it down as a new genus, and has thus, more than any other botanist of equal ability, overloaded the science with useless synonyms. So recklessly, indeed, did he give way to this mania of coining new names, that he on many occasions proposed two, or even three, for the same genus, leaving future botanists to take their choice." CASSINI did not neglect *Campylotheca* in this respect. At the very outset he proposed *Dolicotheca* as an alternative name. This latter name, however, was never adopted by LESSING, DE CANDOLLE, or others.

species that exhibit this character, however, is very small compared with the remaining Pacific species that lack it.[8] Moreover, a study of their other characters, such as odor of bruised foliage (when fresh) and shape of ligules, as well as range of distribution, shows them to be much closer to the wingless-achened *Bidens* species of the Pacific than to the wing-achened American species, *Coreopsis lanceolata* L., that must be taken as the type of the genus *Coreopsis*. It seems wise, therefore, to transfer such species directly to *Bidens* rather than leave them with *Coreopsis*, where originally placed by GRAY. We shall have even then no greater incongruity in *Bidens* than must perforce be tolerated in *Coreopsis*. Thus, for example, all authors who have dealt with the subject have retained the North American wingless-achened *Coreopsis rosea* Nutt. and *C. tinctoria* Nutt. in *Coreopsis* despite their anomalous achenes, because their other characters clearly indicated a closer affinity with *Coreopsis*. Manifestly this was the only correct course to pursue, and my own procedure is precisely comparable.

In the following list, therefore, such transfers are made. In addition, there are transferred certain other species that were described by GRAY under *Coreopsis* (where he placed them because they lacked retrorsely barbed awns; cf. BOT. GAZ. **59**:305–308. 1915), or by HILLEBRAND under *Campylotheca*. The new names are:

Bidens molokaiensis (Hillebr.), comb. nov.—*Campylotheca molokaiensis* Hillebr., Fl. Hawaiian Isls. 212. 1888.

Bidens macrocarpa (Gray), comb. nov.—*Coreopsis* (*Campylotheca*) *macrocarpa* Gray, Proc. Amer. Acad. **5**:126. 1862.

Bidens Remyi (Hillebr.), comb. nov.[9]—*Campylotheca Remyi* Hillebr., *loc. cit.*, 212; *Coreopsis Hillebrandiana* Drake del Cast., Illustr. Fl. Ins. Mar. Pacif. 209. 1890.

[8] Cf. HILLEBRAND'S misleading words, "the winged achenes of so many species." Doubtless HILLEBRAND was recalling many specimens of a few species, and unguardedly referring to them as "so many species." Reference to his individual descriptions shows few of the species to be described as wing-achened.

[9] This species was based by HILLEBRAND upon *M. J. Remy* 287, a single specimen in Gray Herbarium. I have seen not only the type but an excellent duplicate in Paris (Herb. Mus. Hist. Nat.), also fine specimens collected by *Faurie* (Herb. Brit. Mus.), *Forbes* (Herb. Bernice Pauahi Bishop Mus.), etc. The species should not be confused with *Bidens Remyi* Drake del Cast. (Illustr. Fl. Ins. Mar. Pacif. *pl. 39.* 1888; *Coreopsis Remyi* Drake del Cast., *loc. cit.*, 210), a species founded upon *M. J. Remy* 281,

Bidens dichotoma (Hillebr.), comb. nov.—*Compylotheca dichotoma* Hillebr., *loc. cit.*, 212.

Bidens mauiensis (Gray), comb. nov.—*Coreopsis mauiensis* Gray, Proc. Amer. Acad. **5**:125. 1862; *Campylotheca mauiensis* Hillebr., *loc. cit.*, 213.

Bidens cosmoides (Gray), comb. nov.—*Coreopsis* (*Campylotheca*) *cosmoides* Gray, *loc. cit.*, 126.

Bidens Menziesii (Gray), comb. nov.—*Coreopsis* (*Campylotheca*) *Menziesii* Gray, *loc. cit.*, 127.

A most remarkable feature of the flora of the Hawaiian Islands is the large number of endemic species. For a number of years botanists have been cognizant of this pronounced degree of endemism (cf. HILLEBRAND, Fl. Hawaiian Isls. pp. xv and xxv. 1888; MACCAUGHEY, Amer. Botanist **22**:45–52. 1916; BOT. GAZ. **64**:89–114. 1917; *loc. cit.*, **66**:273–275. 1918). Furthermore, the scanty supply of Hawaiian specimens available in most herbaria often makes a proper interpretation of the various endemic forms practically impossible at the present day.

In 1917, almost in despair of being able to arrive at satisfactory opinions respecting several Hawaiian species of *Bidens*, I appealed to certain botanists resident there for aid. One of these, Professor CHARLES N. FORBES, Curator of Botany at the Bernice Pauahi Bishop Museum in Honolulu, proved able to render me assistance of the utmost value. In 1919 he placed at my complete disposal the entire *Bidens* collection of the Bishop Herbarium, also a set of duplicates (later deposited in Field Museum, Chicago). Among these were specimens not only by HILLEBRAND, MANN and BRIGHAM, and other older collectors, but also by FORBES, BRYAN, STOKES, and others of the present century. A considerable portion had

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but which clearly is a mere form of *Bidens micrantha* Gaud. A specimen of *Remy* 281 in Gray Herbarium had been erroneously determined by ASA GRAY as being *Bidens sandvicensis* Less. var. *heterophylla* Gray. Later, HILLEBRAND (*loc. cit.*, 216), having seen this sheet at Gray Herbarium and assuming GRAY'S determination to be correct, naturally equated GRAY'S *B. sandvicensis* var. *heterophylla* with *B. micrantha* Gaud. But the true *B. sandvicensis* Less. var. *heterophylla* Gray was based upon a plant in Kew Herbarium collected by BEECHEY on the Island of Oahu, and treated by HOOKER and ARNOTT as *Bidens luxurians*. This plant of BEECHEY'S is wholly distinct from *B. micrantha* Gaud. and from our *B. Remyi*.

been collected in localities never before visited by botanists. Many of the plants collected even from the better-known localities were much superior in point of maturity and state of preservation to those previously collected by other botanists. No less than eleven species were found to be new. Still other species, while not new to science, were represented in such excellent or numerous forms that more elaborate descriptions and more accurate concepts were possible than when the species were first described. The descriptions, with lists of specimens examined, are presented herewith.

Bidens cervicata, sp. nov.—Glabra, supra herbacea, infra forsan suffruticosa, caule acute tetragono, ramoso, ±8 dm. alto. Folia membranacea, pinnata aut summis tripartita, petiolis adjectis 7–15 cm. longis, foliolis lanceolatis, acuminatis, serratis dentibus acribus et tenuiter mucronatis, sparsim ciliatis, 2.5–9 cm. longis et 0.8–2.8 cm. latis, petiolis tenuibus 1.5–4 cm. longis. Capitula multa, subcorymbosa, ligulata, ad anthesin 5–7 mm. alta et 1.5–1.8 cm. lata. Involucri bracteae exteriores plerumque 5, lineares, glabratae, patentes aut reflexae, 1.5–2.5 mm. longae, interioribus multo breviores. Ligulae circ. 5, flavidae, ovato-lanceolatae vel elliptico-oblongae, apice saepe profunde et acriter dentatae, 7–9 mm. longae. Achaenia tenuiter linearia, nigra, exalata, exaristata, glabra aut 1-paucis setis munita, torta, infra angustata, supra cervici-elongata, 1–1.3 cm. longa.

SPECIMENS EXAMINED.—*C. N. Forbes* 1085 K, Waimea Drainage Basin, west side, Kauai, July 3 to August 18, 1917 (Herb. Bishop Mus., type; Herb. Field Mus., no 485172).

Bidens amplectens, sp. nov.—Herbacea supra, infra verisimiliter suffruticosa, ramosa, caule ramisque tetragonis, glabra, probabiliter 5–8 dm. alta. Folia plerumque pinnata, membranacea, petiolis adjectis 4–12.5 cm. longis et 3–7.5 cm. latis; foliolis 3–5, ovato-lanceolatis, serratis dentibus orbiculatis, ad apicem acuminatis, terminali saepe maiore, petiolis tenuibus 2–4 cm. longis. Capitula non multa, sub-solitaria in pedunculis, laxissime corymbosa, adolescentia iis Cosmi specierum non dissimilia, florescentia 6–8 mm. alta et 3–3.5 cm. lata. Involucri bracteae exteriores 5–6, valde reflexae, crassiusculae, lineari-oblanceolatae, ad apicem

subacutae et glanduloso-apiculatae, 3–6 mm. longae, quam interiores paulo breviores. Ligulae 7–8, anguste obovatae, apice obscure dentulatae, 1.5–1.8 cm. longae. Achaenia submatura nigra, plana, exalata, marginibus apiceque setulosa, exaristata aut obscurissime biaristata, circ. 8 mm. longa.

A plant of peculiar aspect, embracing habital characters of *Cosmos* and *Coreopsis* as well as of *Bidens*, hence the name *amplectens*.

SPECIMENS EXAMINED.—*C. N. Forbes* 1839 O, Kawaihapai, Waianae Range, Oahu, Hawaiian Islands, *sine tempore legendi* (Herb. Bishop Mus., type; Herb. Field Mus., no. 485361).

Bidens micranthoides, sp. nov.—Herba glabrata, infra suffruticosa, supra ramosa, ramis gracilibus, 3–5 dm. alta. Folia pinnata aut rarius ternata, petiolis adjectis 3–7 (–12.5) cm. longis et 2–5 (–8) cm. lata, foliolis ovato-lanceolatis aut raro ovatis, serratis, ad apicem plerumque acutis aut etiam longissime acuminatis, nunc membranaceis, nunc subrugoso-crassiusculis, foliolis imis raro tripartitis, petiolis tenuibis 1–5 cm. longis. Capitula supra folia exserta, laxe corymbosa, ad anthesin 5–7 mm. alta et 1.5–2.5 cm. lata. Involucri bracteae exteriores 5–7, lineares, ad apicem subobtusae, glabratae aut glanduloso-pulverulentae, 1–2.5 mm. longae, interioribus multo longioribus. Ligulae 4–6, flavae, ovato-oblanceolatae, ad apicem 2–4-dentulatae, circa 1 cm. longae. Achaenia linearia, exalata, supra et ad margines sparsim setosa, apice setoso-coronulata et biaristata aristis retrorsum hamosis aut saepe plus minusve exaristata, 7–9 mm. longa.

SPECIMENS EXAMINED.—*Captain Beechey*, Oahu (May 19–30, 1826, *fide* Hook. and Arn., Bot. Beech. Voy. p. i. 1841) (Herb. Hookeri in Herb. Kew); *C. N. Forbes* 494 K, Wailua Falls, Kauai, October 5, 1916 (Herb. Bishop Mus.; Herb. Field Mus., no. 485156); *idem* 592 K, Nonou Mountains, Kauai, October 16–17, 1916 (Herb. Bishop Mus.; Herb. Field Mus., no. 485160); *idem* 704 K, Haupu Range, above Nawiliwili Bay, Kauai, October 31, 1916 (Herb. Bishop Mus., type); *idem* 1405 O, Manoa Valley, Oahu, November 23, 1909 (Herb. Bishop Mus.; Herb. Field Mus., no. 485254); *idem* 1849 O, Waiolani Ridge, Oahu, October 27, 1913 (Herb. Bishop Mus.); *idem* 2014 O, ridge east of Kuliououiki, Oahu, November 17, 1914 (Herb. Bishop Mus.).

As the name suggests, this species resembles more or less *B. micrantha* Gaud. In some cases the resemblance in foliage is very deceiving. The preceding specimen by *Beechey* had been determined as *B. micrantha* by HOOKER and

ARNOTT (cf. Hook. and Arn., Bot. Beech. Voy. 86. 1841), although in this case the foliage was very distinct from that of GAUDICHAUD'S plate for *B. micrantha*. ASA GRAY, who later studied the *Beechey* plant, referred it incorrectly to *B. sandvicensis* Less. (cf. Gray, Proc. Amer. Acad. 5:128. 1862). From both *B. micrantha* and *B. sandvicensis* my species differs most noticeably in habit, being lower in stature, apparently more open in its branching, and certainly with the inflorescence much more open, the heads being variously scattered and at different levels, not so corymbose.

Bidens Stokesii, sp. nov. (pl. XII).—Supra herbacea, infra verisimiliter fruticosa, glabra, caule subtetragono, ramoso, ±6 dm. alto. Folia ternata aut 5 foliolis pinnata, membranacea, non ciliata, petiolis adjectis 4–9 cm. longa et 2.5–6 cm. lata, foliolis rhomboideo-ovatis aut lanceolatis, terminali interdum breviter acuminato, orbiculato-serratis, raro inciso-lobulatis, petiolis tenuibus 1.5–4 cm. longis. Capitula pauca, paniculato-corymbosa, tenuiter pedunculata (ad fines ramorum 10–14 cm. nudorum) pedunculis 1–5.5 cm. longis, ligulata, ad anthesin circ. 7 mm. alta et 2–2.5 cm. lata. Involucri bracteae exteriores circ. 8, lineares, glabratae aut sparsissime hispidae, apice indurato, 3–4 mm. longae, erectae aut recurvatae, interioribus longiores. Ligulae 6–7, flavidae, oblongae, apice obscure dentulatae, 7–10 mm. longae. Achaenia linearia, nigra, glabra, interdum plano-marginata sed non vere alata, saepe biaristata aristis tenuibus et obscure retrorso-hamosis, ±7 mm. longa.

SPECIMENS EXAMINED.—*John F. G. Stokes, sine numero*, foot of plateau, southeast, Niihau, January 1912 (Herb. Bishop Mus., type).

Bidens asplenioides, sp. nov. (pl. XII).—Supra herbacea, infra verisimiliter suffruticosa, glabra, ramosa, caule subtetragono, ±4 dm. alto. Folia submembranacea, pinnata aut ternata, crenata, petiolis adjectis 6–16 cm. longa; foliolis lanceolatis aut anguste ovato-lanceolatis, non ciliatis, terminali ad apicem longe acuminato, 6–8 cm. longo, lateralibus ad apicem acutis vel subobtusis et dimidio brevioribus; petiolis tenuibus 3–7 cm. longis. Capitula multa, ligulata, ad anthesin circ. 1.5–2 cm. lata et 6–8 mm. alta, pedunculis tenuibus 1–6 cm. longis. Involucri bracteae exteriores circ. 5, lineari-spathulatae, demum reflexae, glabratae, circ. 2 mm. longae; interioribus lanceolatae, dimidio longioribus. Ligulae (mancas tantum vidi) flavae, circ. 8–10 mm. longae.

Achaenia (manca vidi) linearia, exalata, supra glabrata aut sparsim setosa, apice nuda aut biaristata, verisimiliter 5–7 mm. longa.

SPECIMENS EXAMINED.—*J. F. G. Stokes*, Kaali, Niihau, January 1912 (Herb. Bishop Mus., type).

The elongate crenate terminal leaflets offer a curious superficial resemblance in outline to the leaves or leaflets of some species of *Asplenium* (*A. pinnatifidum* Nutt. etc.). In shape of leaves, length of petioles, habit of inflorescence, number of capitula, proportionate length of exterior involucral bracts, and various other respects, this species is sharply separate from *B. Stokesii*.

Bidens valida, sp. nov.—Supra herbacea, infra verisimiliter fruticosa, glabra, caule tetragono, valido, ± 7 dm. alto. Folia (exsiccata) atra supra, acriter serrata, non ciliata, petiolis adjectis 4–15 cm. longa; superiora indivisa ovata aut ovato-lanceolata, abrupte acuminata, 2–6 cm. lata; inferiora tripartita (aut interdum pinnata?—tantum unum inferius vidi), foliolis lanceolatis, acuminatis petiolis tenuibus 1–5 cm. longis. Capitula pauca, corymbosa solitaria in pedunculis subtenuibus, maiuscula, involucro ad anthesin circ. 6 mm. alto et (supra) 11 mm. lato, demum circ. 1.4 cm. alto et (supra) 1.2–3 cm. lato; pedunculis saepe bracteatis, 2–11 cm. longis. Involucri bracteae exteriores 7 aut 8, foliosae, obtuse oblongo-lanceolatae, glabrae, apice obscure induratae, demum 1.5–1.8 cm. longae et 2–3 mm. latae, interioribus longiores. Ligulae non observatae. Achaenia linearia, nigra, exalata, glabra aut sparsim setoso-hispida, apice vero exaristata, plerumque sub apicem biaristata aristis brevibus et retrorsum (1–3 setis) hispidis, 8–13 mm. longa.

SPECIMENS EXAMINED.—*C. N. Forbes* 27 K, Haupu near Lihue, Kauai, July 9, 1909 (Herb. Bishop Mus., type; Herb. Field Mus., no. 485137).

Bidens cuneata, sp. nov. (pl. XIII).—Frutex ramosus, verisimiliter 6–10 dm. altus, ramis dichotomis, tenuibus, infra foliosis, supra in pedunculos productis. Folia crassiuscula, rhomboideo-ovata, dentata (dentibus in latere singulo plerumque 3–5), ad apicem acuta, ad basim anguste aut late cuneata, petiolis adjectis 3–5 cm. longis et 1–2 cm. latis, petiolis tenuibus, 1–2 cm. longis. Capitula solitaria, ligulata, ad anthesin circ. 6 mm. alta et 2–2.5 cm. lata, pedunculis tenuibus 0.8–1.8 dm. longis. Involucri bracteae exteriores circ. 7, lineares, glabratae, glandulo-apiculatae, bracteas interiores subaequantes. Ligulae late lanceolatae, flavae, ad

apicem dentulatae, 8–11 mm. longae. Achaenia linearia, exalata, ad margines sparsissime ciliata, ad apicem ciliato-coronata, exaristata, 6–7 mm. longa.

SPECIMENS EXAMINED.—*W. A. Bryan*, Diamond Head, Oahu, in 1903 (Herb. Bishop Mus., type).

Bidens setosa, sp. nov.—Gracilis, glabra, supra herbacea, infra forsan suffruticosa, caule tetragono, ramoso, ±8 dm. alto. Folia membranacea, plus minusve ciliata, saepe sparsissime adpresso-hispida, serrata dentibus mucronatis; summa nunc indivisa, ovata aut lanceolata, ad apicem acuta vel acuminata, petiolis adjectis 3–6 cm. longa, nunc tripartita; inferiora tripartita vel pinnata foliolis ovatis vel lanceolatis, petiolis adjectis 4–7 cm. longa et 2.5–3.5 cm. lata; petiolis tenuissimis, 1–3 cm. longis. Capitula corymboso-paniculata interdum numerosa, parva, ligulata, ad anthesin 5–6 mm. alta et 1.5–2 cm. lata, pedunculis tenerrimis 1–4 cm. longis. Involucri bracteae exteriores 4–6, patentes aut reflexae, lineares, ciliatae et plus minusve pubescentes, 1.5–2.5 mm. longae, interioribus breviores. Ligulae plerumque 5, flavidae, anguste oblongo-ellipticae, apice (saepe profunde et acriter) dentatae, 5.5–8 mm. longae. Achaenia lineari-fusiformia, interiora supra anguste elongata, omnia exalata, exaristata, plerumque valde setoso-hispida setis singulis aut saepe 2–5-aggregatis, apice setoso-coronata, 7–10 mm. longa.

SPECIMENS EXAMINED.—*C. N. Forbes* 811 K, Waimea Drainage Basin, west side, Kauai, July 3 to August 18, 1917 (Herb. Bishop Mus., two type sheets; Herb. Field Mus., no. 485165).

Bidens Forbesii, sp. nov. (pl. XIV).—Herbacea supra, infra verisimiliter fruticosa, caule ramisque tetragonis, glabra, probabiliter 7–10 dm. alta. Folia inferiora magna, tripartita, petiolis adjectis 1–2.5 dm. longa et 5–15 cm. lata, foliolis lanceolatis, longe acuminatis, membranaceis, creberrime serratis dentibus acribus et longe mucronulato-inflexis, 1–1.4 dm. longis et 3.5–5 cm. latis, petiolis tenuibus 6–8 cm. longis; foliis superis minoribus, 7–10 cm. longis et 4–5 cm. latis. Capitula parva, supra folia exserta, subcorymbosa, ad anthesin 4–5 mm. alta et circ. 1.5 cm. lata. Involucri bracteae exteriores circ. 3–4, anguste lineares, ad apicem acutae, glanduloso-pulverulentae aut fere glabratae, patentes aut

reflexae, circ. 1.5 mm. longae, interioribus paulo longioribus. Ligulae circ. 5, flavidae, anguste oblongo-obovatae, apice valde acriterque 2-dentatae, 6–8 mm. longae. Unum achaenium maturum visum nigrum, valde arcuatum et tortum, glabrum, exalatum, exaristatum, circ. 1 cm. longum; achaeniis immaturissimis biaristatis, aristis retrorsum 1–2-hamosis.

SPECIMENS EXAMINED.—*C. N. Forbes* 82 K, Waioli Valley, Kauai, July 23, 1909 (Herb. Bishop Mus., two type sheets).

Bidens waianensis, sp. nov.—Frutex glaber, supra ramosus, verisimiliter 5–8 dm. altus. Folia gracilia, pinnata aut plus minusve bipinnata, petiolis adjectis 4–12 cm. longa et 3–6 cm. lata, foliolis primariis lanceolatis serratis acuminatis aut iterum pinnatis lobis ultimis linearibus integris ad apicem acriter mucronatis, petiolis tenuissime 2–4 cm. longis. Capitula multa, corymbosa aut corymboso-paniculata, ad anthesin circ. 6 mm. alta et 1.5–2 cm. lata, breviter supra folia exserta, floribus 15–25. Involucri bracteae exteriores circ. 6, lineares, glabratae aut sparsim glanduloso-pulverulentae, ad apicem subacutae, 1–2 mm. longae, quam bracteae interiores dimidio breviores. Ligulae circ. 5, flavidae, oblongo-oblanceolatae, ad apicem obtusae, circ. 1 cm. longae. Achaenia nigra, valde torta, glabra aut versus apicem remote setosa, exalata matura exaristata et 6–10 mm. longa.

SPECIMENS EXAMINED.—*C. N. Forbes* 2023 O, Kolekole Pass, Waianae Range, Oahu, February 1 and 2, 1915 (Herb. Field Mus., no. 485291, type; Herb. Bishop Mus., a form with leaflets much broader than in the type specimen); U.S. S. Pacif. Expl. Exped. (under *Captain Wilkes*), Kaala Mountains, Waianae Range, Oahu, 1838–1842 (Herb. Bishop Mus.; Herb. New York Bot. Gard., two sheets); *J. F. G. Stokes*, Kolekole Pass, Waianae Range, Oahu, in 1915 (Herb. Bishop Mus.).

ASA GRAY had determined the specimens collected under Captain WILKES as being *Bidens micrantha* Gaud. (*Coreopsis micrantha* Gray). Later, in discussing *Bidens micrantha* (Proc. Amer. Acad. **5**:127. 1862), he said: "Sandwich Islands, especially Oahu. Variable in the foliage, which is commonly more dissected than in GAUDICHAUD'S figure." Clearly GRAY had in mind the *Wilkes* plants, collected in the Waianae Range on Oahu. A study of the more recent specimens by FORBES and by STOKES, collected in the same immediate locality, shows the identical peculiarities of foliage. Furthermore, the floral and achenial characters are seen to be very distinct from those of the more widely distributed *Bidens micrantha*, which occurs not only on Oahu but also on Hawaii, Maui, and Lanai.

Bidens torta, sp. nov.—Fruticosa, glabra, caule non crasso ±5 dm. alta. Folia tripartita, membranacea, serrata, ciliata, tenerrime petiolata, petiolis adjectis 7–16 cm. longa et 2.5–10 cm. lata, foliolis acuminatis, terminali multo maiore, oblongo-lanceolato, lateralibus sessilibus aut breviter petiolulatis, ovato-lanceolatis, petiolis 1–4 cm. longis. Capitula numerosa, laxe paniculata, mediocria, ligulata, ad anthesin circ. 5 mm. alta et 1.7 mm. lata. Involucri bracteae exteriores circ. 5, tenuiter lineares, glanduloso-pubescentes, 1.5–2.5 mm. longae, interioribus paulo breviores. Ligulae circ. 5, oblongo-oblanceolatae, flavae, ad apicem plus minusve dentulatae, circ. 7 mm. longae. Achaenia tenuiter linearia, nigra, maxime torta, glabra, corpore 9–13 mm. longa ad apicem calva aut obscure 1–2-aristata aristis glabris brevissimis (0.1–0.3 mm. longis).

SPECIMENS EXAMINED.—*C. N. Forbes* 2092 O, Kawailoa, Oahu, March 2–5, 1915 (Herb. Bishop Mus., type; Herb. Field Mus., no. 485294).

The leaves of this species appear to have rather large leaflets in proportion to the thickness of the petiole. The terminal leaflet becomes 1 dm. long and 4.4 cm. wide. The branches of the inflorescence are slender and widely diverging. The leaves and inflorescence combine to give a striking superficial resemblance to certain Central American specimens of *B. squarrosa* H. B. K. The achenes surpass those of nearly all other species in the amount of twisting. The twisting commences early, in the young achene, and the mature achenes are frequently twisted through four or five complete revolutions.

BIDENS GRACILIS Nutt., Trans. Amer. Phil. Soc. Ser. II. **7**:368. 1841; *Campylotheca gracilis* Walp., Rept. Bot. Syst. **2**:618. 1843.—No described species of *Bidens* has been left heretofore in greater obscurity than *B. gracilis*. From the time of NUTTALL'S original description, no botanist appears to have given it serious attention. In 1843 WALPER categorically transferred the species, along with two others described by NUTTALL, to *Campylotheca*. In 1862 GRAY (Proc. Amer. Acad. **5**:128) referred it, along with *Bidens mutica* Nutt., to *B. sandvicensis* Less. NUTTALL'S types of *B. gracilis* and *B. mutica* are still extant in a state of excellent preservation (Herb. Brit. Mus.). The type of *B. gracilis* is clearly distinct from that of *B. mutica*. It is distinct also from the specimens that I assume to be of the type collection of *B. sandvicensis* Less. by CHAMISSO from Oahu (for example, *distrib. Acad. Petropol. in Hb. Kew, ex Hb. Hookeri*). In 1888 HILLEBRAND doubtfully referred

the species to a variety of *Bidens macrocarpa*, but NUTTALL's type is not even remotely matched by the type material (Herb. U.S. Nat. Mus.; Herb. N.Y. Bot. Gard.; Herb. Gray) of *B. macrocarpa*. It is, however, the same as *Mann* and *Brigham* 98, distributed to various herbaria as *B. hawaiensis*. *B. hawaiensis* is a much coarser plant and differs in many characters from *B. gracilis*. From all other species of the Hawaiian Islands *B. gracilis* is sharply distinct. From the several specimens studied, I have drawn up the following amplified description:

BIDENS GRACILIS Nutt., descript. amplificat. (pl. XIII).—Frutex gracilis, glabra, ramosa ramis rubescentibus, verisimiliter 6–9 dm. alta. Folia plerumque serrata aut etiam laciniato-dentata, acuminata; nunc indivisa et ovata aut lanceolata, petiolis adjectis 3–7.5 cm. longa et 1–2 cm. lata; nunc tripartita, foliolis lanceolatis, foliolo terminali 4–5 cm. longo et 1–1.5 cm. lato, lateralibus dimidio minora; petiolis tenuibus, 1–2 cm. longis. Capitula parva, paniculata paniculis trichotomis, ligulata, ad anthesin 6–7 mm. alta et circ. 1 cm. lata, pedunculis gracilibus 0.5–2.5 cm. longis. Involucri bracteae exteriores lineares, patulae, supra subglandulosae, interioribus adpressis fere dimidio breviores. Ligulae circ. 5, lanceolatae, flavae, ad apicem dentatae, 3–6 mm. longae. Achaenia torta, linearia, corpore ± 8 mm. longa, facie et marginibus glabra aut sparsissime hispida, apice setuloso-ciliata, nunc brevissime biaristata aristis 0.3–0.8 mm. longis et glabris aut versus apicem retrorsum hispidulis, nunc uniaristata aut etiam exaristata, saepe omnibus tribus formis in eodem capitulo.

SPECIMENS EXAMINED.—*Thos. Nuttall*, Oahu (Herb. Brit. Mus., type); *Mann* and *Brigham* 98, Oahu (Herb. Bishop Mus.; Herb. Cornell Univ.; Herb. Field Mus.); *C. N. Forbes* 1184 O, Moanalua Valley, Oahu, March 9, 1909 (Herb. Bishop Mus.).

BIDENS MICRANTHA Gaud. Voy. Freycinet Bot. 464. *pl. 85*. 1826–1829.—*Campylotheca micrantha* Cass. Dict. Sci. **51**:475. 1827; *Coreopsis micrantha* Gray, Proc. Amer. Acad. **5**:127. 1861; *Bidens Remyi* Drake del Cast. Illustr. Fl. Ins. Mar. Pacif. *pl. 39*. 1888; *Coreopsis Remyi* Drake del Cast., *loc. cit.*, 210.—The identity of *Bidens micrantha* Gaud. has long been a matter of conjecture with most authors. Many appear to have assumed that GAUDI-

CHAUD's original plate was only a crude representation, and that hence the delineation of foliage, etc., given there must not be interpreted very literally. Consequently, various other species have been referred arbitrarily to *B. micrantha* to such an extent that references in literature to *B. micrantha* Gaud. are almost entirely untrustworthy. In studying the recent collections from the Hawaiian Islands, I was impressed with the resemblance of a certain plant (*G. C. Munro* 602, see later) to GAUDICHAUD's illustration. The leaves possessed the same peculiar outlines as in the drawing. A careful study of the plant showed that it was positively the true *B. micrantha*. Several other plants that, while varying in various minor details from this plant, were seen to belong nevertheless with it specifically, were then assembled. From this small group of specimens I have been able to draw up the following amplified description.

BIDENS MICRANTHA Gaud., descript. amplificat.—Frutex glabra, caule plus minusve rubido, 6–9 dm. alta. Folia gracilia, crassiuscula, irregulariter 3–5-foliolata aut summa simplicia, petiolis adjectis 4–13 cm. longis, foliolis anguste lanceolatis, acuminatis, utroque latere paucis dentulis ad medium serrato, 2–5 cm. longis et 4–12 mm. latis, petiolis 1.5–5 cm. longis. Capitula numerosa, paniculata aut corymbosa, ligulata, ad anthesin 4–6 mm. alta et 1.5–2 cm. lata, pedicellis tenerrimis 1–2.5 cm. longis. Involucri bracteae exteriores lineares, resino-pubescentes aut glabratae, minimae (circ. 1.5 mm. longae), bracteis interioribus multo minora. Ligulae 3–5, anguste oblongae, flavae, saepe ad apicem obscure dentatae, circ. 1 cm. longae. Achaenia linearia, nigra, compressa, recta vel torta, facie et marginibus plerumque glabra, 7–10 mm. longa, apice nunc exaristata et setosa, nunc breviter biaristata aut etiam (marginibus excurrentibus sub apicem) irregulariter quadriaristata, aristis glabris aut retrorsum hispidulis.

SPECIMENS EXAMINED.—*M. J. Remy* 281, Hawaii, 1851–1855 (Herb. Gray; Herb. Mus. Hist. Nat. Paris; type material of *Bidens Remyi* Drake del Cast. *non nobis; Coreopsis Remyi* Drake del Cast.); *C. N. Forbes* 14 H., Puuwaawaa, Hawaii, June 8–14, 1911 (Herb. Bishop Mus.); *idem* 326 Mo., ridge and foot of Lahainaluna Valley, Maui, February 1913 (Herb. Bishop Mus.); *G. C. Munro* 602, ridge to Puu Kukui, Maui, September 26, 1916 (Herb. Bishop Mus.; one of the achenes was 3-awned!); *idem* 122, Waiapaa, Lanai, September 26, 1913

(Herb. Bishop Mus.; form very close to GAUDICHAUD's original plate); *C. N. Forbes*, Kaala Mountains, Makaha Valley, Oahu, February 12–17, 1909 (Herb. Bishop Mus.; Herb. Field Mus., no. 485330; a form somewhat atypic as to foliage); *Hillebrand* and *Lydgate*, Kula, Maui (Herb. Bishop Mus.).

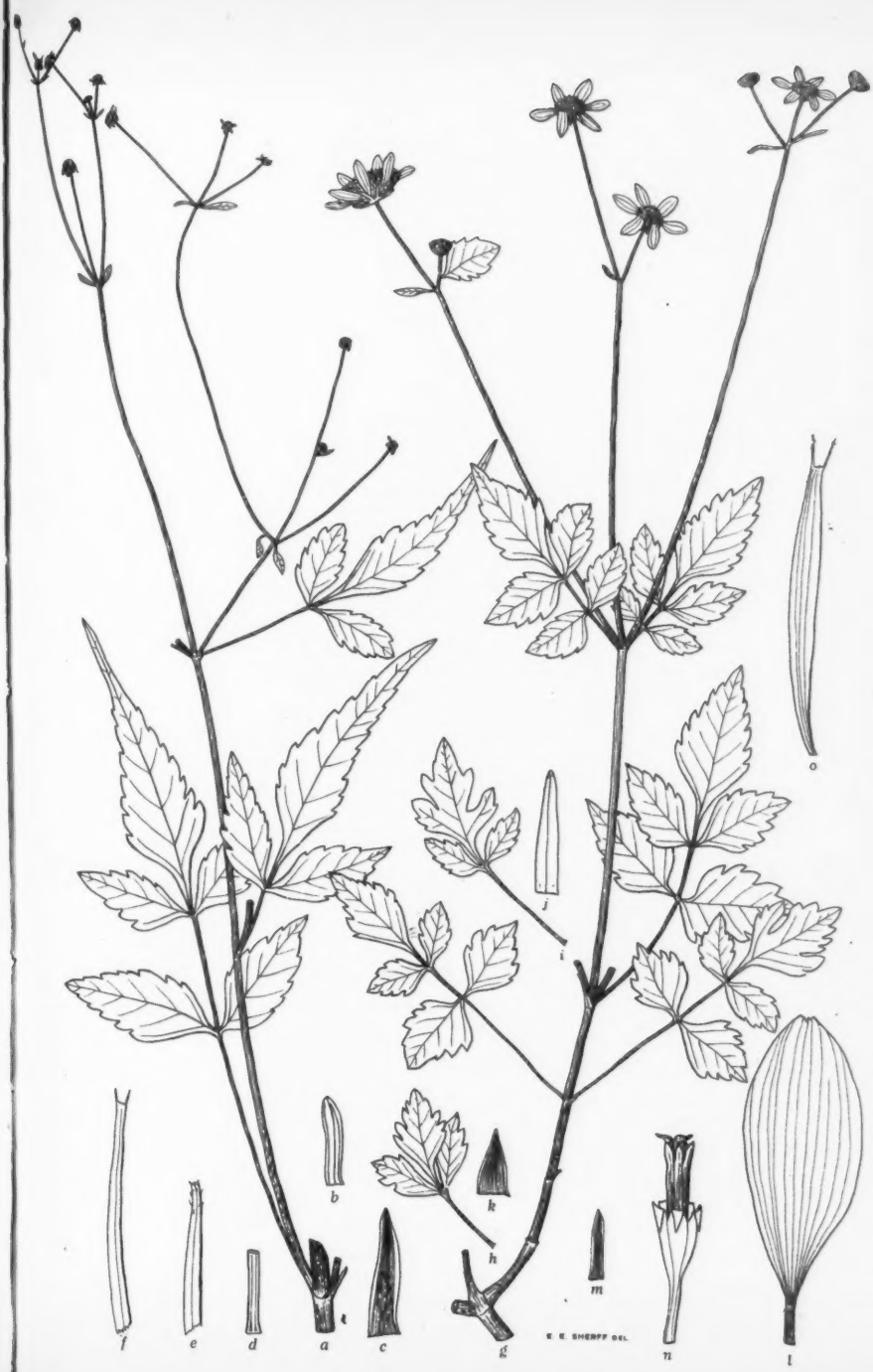
BIDENS MACROCARPA (Gray) Sherff.—*Coreopsis* (*Campylotheca*) macrocarpa Gray, Proc. Amer. Acad. **5**:126. 1862.

BIDENS MACROCARPA, descript. amplificat.—Fruticosa, erecta, glabra (1–1.6 m. alta fide Hillebr. Fl. Haw. 214. 1888). Folia subcrassa, ternata aut pinnata aut summa saepe maximam partem simplicia, petiolo adjecto 0.5–2.2 dm. longa; foliolis (3–5) ovatis aut ovato-lanceolatis, cuspidatis, acriter et saepe creberrime serratis (dentibus interdum valde inflexis), lateralibus 2–6 cm. longis et 1–2 cm. latis, terminali maiore et saepius acuminato, petiolulis lateralium plerumque 2–15 mm. longis; petiolis tenuibus, 2–10 cm. longis. Inflorescentia laxa, aperta, foliolis linearibus vestita, folia superans; capitulis non numerosis, non minutis, ligulatis, ad anthesin 7–8 mm. altis et circ. 3 cm. latis. Involucri bracteae subaequales, exteriores (5–7) crassae, late lineares, glabrae, circ. 6 mm. longae. Ligulae (5–7) flavae, trifida, 1–1.6 cm. longae; disci floribus 15–20. Achaenia pro capitulo magna, late linearia, striata, glaberrima aut marginibus et apice setulosa, erecta aut subtorta, 1.2–2 cm. longa, exalata aut anguste alata, alis in duo dentes aut aristas sub achaeni corporis apicem productis; aristis remotissime et minutissime, antrorsum et retrorsum barbatis, raro glabratis.

SPECIMENS EXAMINED.—*Capt. Wilkes*, U.S. S. Pacif. Expl. Exped., 1838–1842, Oahu (Herb. U.S. Nat. Mus., type; Herb. N.Y. Bot. Gard.; Herb. Gray); *Hillebrand* and *Lydgate*, Konahuanui, Oahu, Hawaiian Islands, October 1872 (Herb. Bishop Mus.); *A. A. Heller* 2901, on and near the summit of Konahuanui, Oahu, November 2, 1895 (Herb. Mo. Bot. Gard.; Herb. N.Y. Bot. Gard.; Herb. U.S. Nat. Mus.); *C. N. Forbes* 2221 O, Wahiawa-Kahana trail, Oahu, August 17–20, 1915 (Herb. Bishop Mus.); *idem*, Palolo Valley ridges, Oahu, December 17, 1908 (Herb. Bishop Mus.); *idem* 2313 O, ridge and foot, Kalihi Valley, Oahu, March 9, 1916 (Herb. Bishop Mus.); *idem*, Lanihuli Trail, Oahu, October 14, 1908 (Herb. Bishop Mus.); *idem*, Koolauloa Mountains between Punaluu and Kaipapau, Oahu, May 3–8, 1909 (Herb. Bishop Mus.); *idem* 2553 O, Manoa Ridge, Oahu, March 17, 1919 (Herb. Bishop Mus.).

A distinguishing character of this species is the appearance of the large fruiting heads. The achenes become elongate, wide, thickish, and usually very glabrous. In no other species is the tendency to have awns placed below the achene's top (that is, upon the margins and more or less decurrent with the achene edge or wing) more pronounced than here.

SHERFF on BIDENS



SHERFF on BIDENS

SHERFF on BIDENS

SHERFF on BIDENS

Bidens linearifolia (O. and H.), comb. nov.—*Coreopsis linearifolia* Oliver and Hiern, Fl. Afr. Trop. **3**:390. 1877; *Bidens Schweinfurthii* Sherff, Bot. Gaz. **59**:309. 1915.—In 1915, on finding it necessary to transfer this species from *Coreopsis* to *Bidens*, I purposely created the new name *Bidens Schweinfurthii* "to avoid any possible confusion with *Bidens linearifolia* Schz. Bip." (Bot. Gaz. **59**:309). This appeared to me to be much the most desirable procedure. Nevertheless, in view of the fact that *Bidens linearifolia* Schz. Bip. is not a true *Bidens*, but is rather a species of *Cosmos* (*C. linearifolius* Hemsley, Biol. Centr. Amer. **2**:200. 1881), the International Rules require the retention of Oliver and Hiern's trivial name.

University of Chicago

EXPLANATION OF PLATES XI–XIV

PLATE XI

Bidens exigua (*a–f'*) and *B. duranginensis* (*g–m'*): *a*, an entire plant ×0.64; *a'*, fruiting head ×0.64; *b*, *b'*, exterior involucral bracts ×5; *c*, interior involucral bract ×5; *d*, palea ×5; *e*, disk floret ×5; *f*, *f'*, outer and inner achenes ×5; *g*, branch and portion of main stem ×0.64; *h*, exterior involucral bract ×5; *i*, interior involucral bract ×5; *j*, ligulate floret ×5; *k*, palea ×5; *l*, disk floret ×5; *m*, *m'*, outer and inner achenes ×5; *a–f'*, from type of *B. exigua* in U.S. Nat. Herb.; *g–m'*, from type of *B. duranginensis* in Herb. Gray.

PLATE XII

Bidens asplenioides (*a–f*) and *B. Stokesii* (*g–o*): *a*, branch ×0.61; *b*, exterior involucral bract ×6; *c*, interior involucral bract ×6; *d*, ovary ×6; *e* and *f*, fragments of mature achenes ×6; *g–i*, branch and additional leaves ×0.61; *j*, exterior involucral bract ×6; *k*, interior involucral bract ×6; *l*, ligulate floret ×6; *m*, palea ×6; *n*, disk floret ×6; *o*, achene ×6; *a–f*, from type of *B. asplenioides*, *g–o*, from type of *B. Stokesii*, both in Herb. Bishop Mus.

PLATE XIII

Bidens gracilis (*a–i*) and *B. cuneata* (*j–p*): *a*, branch ×0.71; *b*, leaf ×0.71; *c*, exterior involucral bract ×7; *d*, interior involucral bract ×7; *e*, ligulate floret ×7; *f*, palea ×7; *g*, disk floret ×7; *h* and *i*, achenes ×7; *j*, branch and two old peduncles, apparently of previous season's growth ×0.71; *k*, exterior involucral bract ×5; *l*, interior involucral bract ×5; *m*, ligulate floret ×5; *n*, palea ×5; *o*, disk floret ×5; *p*, achene ×5; *a*, *c–i*, from *Mann* and *Brigham* 98, Herb. Bishop Mus.; *b*, illustrating trifoliate leaf, from *Forbes* 1184 O. Herb. Bishop Mus.; *j–p*, from type of *B. cuneata*, Herb. Bishop Mus.

PLATE XIV

Bidens Forbesii: *a*, upper portion of plant ×0.61; *b*, leaf from sterile branch ×0.61; *c*, exterior involucral bract ×6; *d*, interior involucral bract ×6; *e*, ligulate floret ×6; *f*, palea ×6; *g*, disk floret ×6; *h*, very young achene ×6; *i*, mature achene ×6; *a*, *c–i*, from first type sheet, *b*, from second type sheet in Herb. Bishop Mus.

STEM ANATOMY OF DIOON SPINULOSUM

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 270

LADEMA M. LANGDON

(WITH PLATES XV–XVII AND FOUR FIGURES)

Introduction

Investigations dealing with the minute anatomical structure of the adult cycad stem have become very numerous and more or less thorough for all of the genera and many of the species, with the exception of the great Mexican representative, *Dioon spinulosum*. This unique and interesting species was first but inadequately described by EICHLER (6) in 1883, and by DYER (5) in 1885. The first extensive account of its general field characters, size, external structure, and distribution was by CHAMBERLAIN (1) in 1909. A later article (2) by the same author gives a full and careful description of the macroscopic structure of adult stems of *Dioon spinulosum*, *D. edule*, *Ceratozamia mexicana*, and *Zamia floridana*, particular attention being given to *D. spinulosum*. Special study is made of the growth rings, reported here for the first time in cycads, and of the medullary bundles which constitute the vascular system of the cones, and which are called cone domes, because of the domelike arrangement of these strands with the peduncle of the cone at their apex. The histological characters of the trunk, its growth rings, the thick-walled fibers of the phloem, and the structure of the xylem elements the author considers remarkably similar to the corresponding structures of *Cycadeoidea*.

The embryo and seedling of *D. spinulosum* have been studied recently by Sister HELEN ANGELA (4), and found in the arrangement and orientation of the vascular strands in the cotyledons, hypocotyl, stem, and leaves to differ in no marked degree from the usual cycad arrangement. Features particularly worthy of note in connection with the girdling habit, as this investigator has traced it from macerated seedling stems, is that each leaf is supplied with five strands arising from cauline bundles situated in different parts

of the stem, and further, that these girdling strands are horizontal from the beginning and continue so throughout their whole extent.

The investigation here described was undertaken with a view to supplementing CHAMBERLAIN's general account of the histological structure of the adult stem of *D. spinulosum*, especially by a careful study of the broad foliar rays or leaf gaps with their included traces, a phase of cycadean anatomy only slightly touched upon by earlier investigators. As the work has progressed, its scope has been extended to include the general course and organization of the foliar strands in the cortical part of both adult and seedling stems.

Material and methods

The adult wood and abundant material of two- and three-year-old seedlings, which furnish the basis for this study, were secured by CHAMBERLAIN from the Hacienda de Joliet near Tierra Blanca, Mexico. The ten-year-old seedlings were from seeds procured in the same locality but germinated and grown in the botanical greenhouse of the University of Chicago.

Preparation of all material of the adult stem for sectioning was in the main as follows. Narrow, wedge-shaped sections extending radially from pith to cortex were cut from both the upper and lower portions of a trunk 18 ft. in height, care being taken that each included two or more of the large medullary rays. These sections were then cut into blocks about 1 cm. square, some slightly larger, and kept in series.

The various stages involved in the preparation of these blocks for sectioning, namely, demineralization of the woody tissues through the use of hydrofluoric acid, followed by a thorough washing of the material in running water to free it from all traces of the reagent, transference to various grades of alcohol and xylol, and finally imbedding in paraffin, have been discussed in a previous paper (**8**). Special care had to be taken in imbedding, the best results being obtained when the blocks were carried through the process of infiltration with paraffin from 48 hours to 3 days. After this they could easily be cut with a sliding microtome, and a complete series obtained by removing each section, as cut, from the knife and placing it directly upon the slide. Staining was with

safranin and gentian violet, or safranin and "licht grün," the latter combination proving the more satisfactory.

The greater part of the study of the girdling habit in the seedlings was made from cleared material. Entire sections comprising stem cylinder and cortex, in blocks 0.5×1 inch, were cleared so perfectly that it was possible, with the aid of a strong artificial light, to look through such a section and see the vascular strands clearly outlined in the cortex.

In the case of the two- and three-year-old seedlings, the method followed consisted in severing the long taproot from the stem just below the region of the cotyledonary plate and cutting off the long terminal leaves, leaving only the leaf bases and a small part of the petiole. The scale leaves were then carefully trimmed from two sides of the stem, and one clean longitudinal cut made through the entire stem from apex to base. After the transference of these half-sections to 50 per cent alcohol (each seedling being kept in a separate receptacle), the process was substantially the same as that for the paraffin method, that is, up to the pure xylol stage. At this point the material was subjected to vacuum treatment in order to free the tissues, as far as possible, of any air or gases they might contain. As a final clearing agent a mixture of xylol and carbon disulphide was used; the CS_2, having a higher refractive index, rendered the material more transparent than pure xylol.

Adult stem

With the single exception of the Australian *Macrozamia Hopei*, *Dioon spinulosum* Dyer is the tallest of all cycads, ranging 10–30 ft. in height, with occasional specimens reaching 40 and even 50 ft. The particular specimen from which this study was made was about 18 ft. tall and possibly 100 years old. The width of the woody zone from pith to cortex averages 0.5–0.75 inch in the upper part of the trunk and 3.5–4 inches in the lower trunk.

STRUCTURE OF XYLEM.—The adult stele of *D. spinulosum* is endarch, and its compact woody cylinder consists chiefly of longitudinal tracheidal elements and radial parenchyma. From the pith to the cortical part of the stem the length of the tracheids averages as follows: scalariform metaxylem tracheids 4–4.2 mm.,

first pitted tracheids 5–6.5 mm., tracheids in the vicinity of the cambium 7–9.8 mm.

The protoxylem elements are of the reticulate and scalariform types, and in passing from the metaxylem to the first formed elements of the secondary wood all transitional stages occur in the reduction of the scalariform structure into imperfectly formed, multiseriate, bordered pits.

While the majority of the tracheids of the secondary xylem exhibit on their radial walls the multiseriate type of pitting so characteristic of this wood, many of the tracheidal elements, especially those constituting the secondarily formed wood in the upper trunk, have their radial walls covered with small bordered pits of a very irregular arrangement.

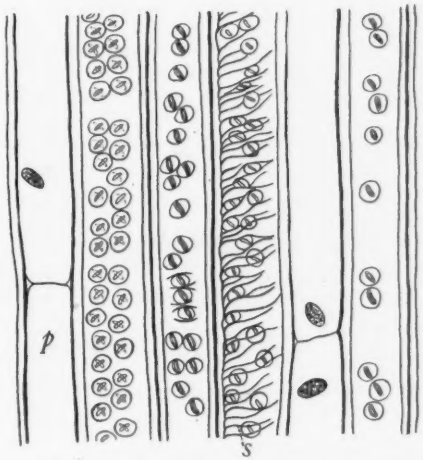


FIG. 1.—Radial longitudinal section of tracheids from lower portion of adult trunk: *s*, tertiary spiral thickenings of tracheid walls; *p*, wood parenchyma; ×225.

In the wood of the lower trunk tertiary spiral thickenings of the tracheid walls were observed occurring in the first few rings of growth and also in the older wood (fig. 1). These spirals are not common to all the tracheids, but are generally sporadic in their appearance and may be quite inconspicuous. In some cases, however, they are characterized by considerable prominence, and are so compact as to suggest a reticulate rather than a spiral formation.

In addition to the lignified elements of the wood there are narrow elongated cells with transverse walls, the longitudinal storage parenchyma. These cells, like those of the radially disposed

bands of parenchyma, are usually well filled with starch and occasional calcium oxalate crystals.

MEDULLARY RAYS.—The medullary rays are of three types, namely, narrow uniseriate rays, a single layer of cells wide and several cells deep; multiseriate rays, two to several cells in width at their widest point and of variable longitudinal extent; and broad foliar rays or leaf gaps, which in tangential view resemble the aggregate ray of *Quercus*. The last are distributed at fairly equal intervals throughout the woody cylinder and always extend from the pith to the cortex. They are further characterized by the presence of at least one mucilage duct and one leaf trace bundle situated in the lower central part of the gap (fig. 6). A few isolated cases occur where two ducts and even two traces may be seen in a single foliar ray.

Course and structure of leaf trace in gap

The course of the leaf trace through the parenchymatous gaps or foliar rays from pith to phloem is approximately level, except for a slight downward curve of the strands due to their manner of formation. The bundle is endarch throughout its course in the gap and through the phloem, the xylem of the bundle usually uppermost and just beneath the duct, with no change in orientation until the bundle reaches the cortex, where it is continuous with one of the oblique cortical strands.

The manner of connection of this foliar trace with the primary and secondary wood of the main stele is one of the most striking and interesting features of the wood. Within a short distance of the pith the strands of the trace curve downward, the primary and secondary elements uniting with like elements of the main cylinder. On the interior vertical face of the wood at the point of union, and continuing up through the gap, always on the upper side of the trace (figs. 3–5) where the primary vessels of the trace would naturally appear, are peculiar tracheidal elements, curiously reticulated, in some cases forming continuous vessels, in other cases merely isolated patches of lignified tissue. These irregular fibrous elements are best illustrated in fig. 2, where a longitudinal section of the upper portion of the trace appears in a transverse section of the wood.

WORSDELL (12) also calls attention to the occurrence of peculiar irregular tracheids resembling "transfusion-tissue" on the interior vertical face of the wood and accompanying the bundles of the large medullary rays of *Macrozamia Fraseri*, and also found among

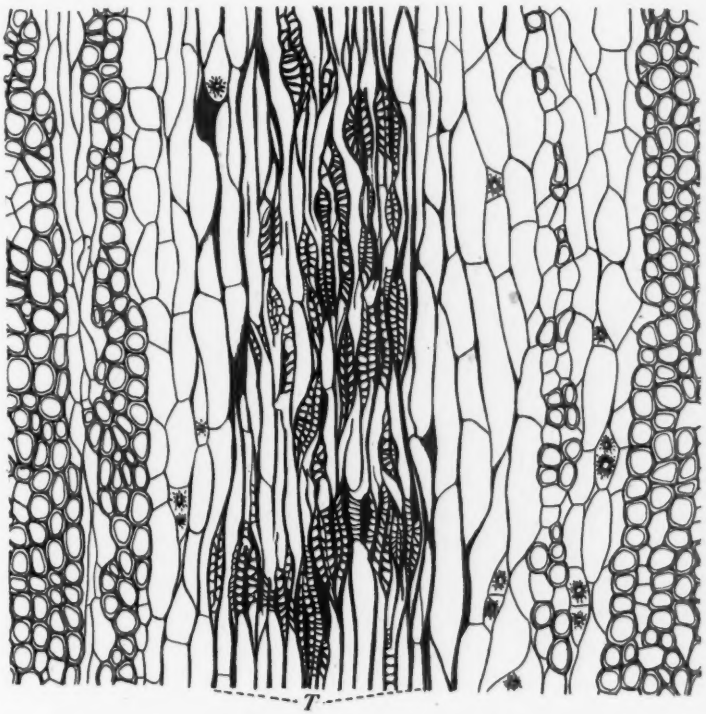


FIG. 2.—Transverse section of mature wood, showing foliar ray in center: *T*, longitudinal section through upper part of leaf trace; ×85.

the parenchyma cells between successive vascular rings in *Encephalartos* (13). These, however, are of a pitted type rather than of the irregularly reticulated and scalariform types characteristic of *D. spinulosum*.

The mode of connection of this trace with the secondary fibrovascular structures of the stem is as follows. Figs. 3, 4, and 5 are

radial longitudinal sections of the large medullary ray with its included foliar strand. A careful study of a series of such radial sections through the trace has made it apparent that this connection is by means of long, irregularly shaped scalariform tracheids which are the real tracheids constituting the trace, and not mere con-

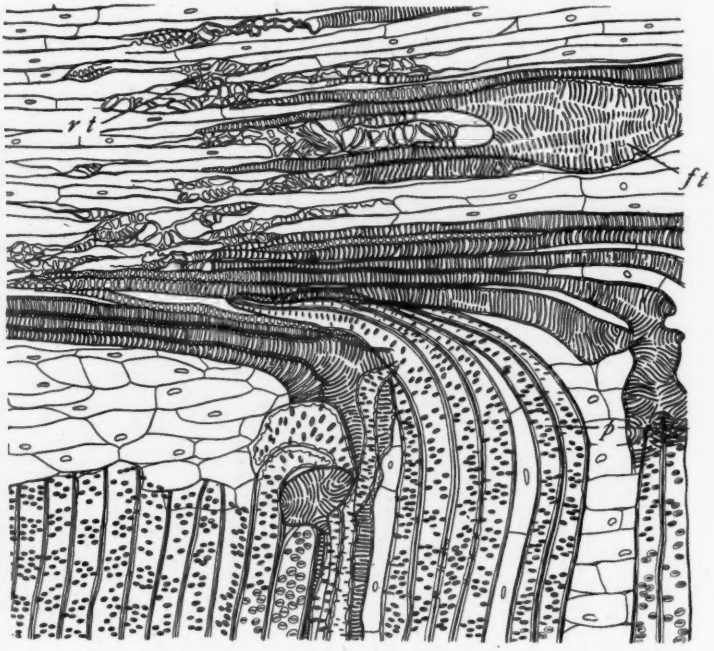


FIG. 3.—Radial longitudinal section of portion of large medullary ray with included foliar strand: *ft*, peculiar tracheidal formation apparently resulting from fusion of two or more tracheids; *rt*, irregularly reticulated elements; ×90.

necting elements, as generally believed. These vessels may be entirely scalariform in structure, or may change gradually from a reticulate type at their tapering ends to decidedly scalariform throughout the greater part of their horizontal and vertical extent. As they extend horizontally through the gap they are arranged in order of formation, one vessel beneath the other (figs. 4, 5), the

lowest and last formed continuing a little farther in the direction of the cortex than the one preceding. In this way they constitute a perfectly continuous conducting system for solutions passing out to the cortical strands. These tracheids are especially numerous a short distance behind the pith, just beyond the primary xylem, but passing on through the gap they appear to become grouped (fig. 5), occurring at intervals with great masses of phloem and parenchyma separating the basal parts of each group. Whether this grouping is associated with a seasonal increase in the length of the trace, corresponding to the radial increase and growth rings of the main stele, has not been determined. In addition to the reticulate and scalariform elements constituting these traces, the regular pitted tracheids of the secondary xylem, usually at the extreme lateral borders of the gap, are often diverted to one side into a direction more or less parallel to that of the trace, as shown in figs. 3 and 5.

WORSDELL (12) has described in the case of *Macrozamia Fraseri* a somewhat similar connection between the fibrous strands in the large medullary rays and the fibrovascular elements of the main stele. He states that "a characteristic feature of the radial section of the wood is the large number of outbending strands of tracheids which, passing through the medullary rays, are continuous with the girdle leaf trace of the cortex." It is worthy of note, however, that these strands of outbending tracheids, or rather inbending in the sense that they are apparently diverted from the direction of the other secondary xylem elements toward that of the rays, are of the pitted type throughout their length, thus homologous with the pitted elements described in the preceding paragraph.

The peculiar down-curving growth of the scalariform tracheids constituting the foliar strands in the large medullary rays of *D. spinulosum* is another interesting illustration of the much discussed phenomenon of gliding growth. Vertically these conducting elements may extend merely to the lower borders of the gap and terminate in the irregular bulbous formations illustrated in fig. 4*B*, or they may become inserted for a considerable depth between the perpendicular fibrous elements of the main stele (fig. 5*sc*). In their horizontal extent these tracheids may be and probably are

the product of cambial activity, but in their vertical enlargement and elongation it seems probable that these lignified elements have simply been stretched out into their curious bending shapes by the growth of the adjoining living parenchyma tissue. The close scalariform markings on these vessels, in some cases approaching almost a pitted character, would indicate that this growth or elongation has taken place gradually, keeping pace with the longitudinal expansion of the gap.

It is also evident that the basal portions of many of these vessels have their origin in quite a different manner. The character of the pitting indicates that there has been a gradual lignification of the ordinary parenchyma cells (fig. 4*B*), and a subsequent fusion by the breaking down and reabsorption of the partition walls. The formation of the peculiar curved and bulbous-like bases of many of these tracheids, where they come in contact with the perpendicular elements of the secondary wood, is shown in this way.

Course of leaf traces in cortex

The course of the fibrovascular bundles in the cortex, complicated by the well known habit of girdling, was first described by KARSTEN (7) in *Zamia muricata*, in 1856, later, in 1861, by METTENIUS (10), and in more recent articles quite fully by THIESSEN and Sister HELEN ANGELA in seedlings of *Ceratozamia* (3), *Dioon edule* (11), and *D. spinulosum* (4).

A brief statement of the girdling situation in the embryo and seedling of *Dioon edule*, as described by THIESSEN, is approximately as follows. For each leaf or scale leaf there are four distinct strands leaving the vascular cylinder. Two of these leave on the same side as the leaf for which they are destined, and pursue a direct course through the cortex to the central part of the petiole without branching; while the other two strands leave the cylinder approximately on the opposite side, describe a wide curve around it, and finally enter the dorsal part of the leaf petiole, where they branch repeatedly.

Sister HELEN ANGELA (4) has described a similar situation and arrangement of the cortical traces in the seedlings of *Dioon spinulosum*. Both authors agree that there are 4 or 5 strands leaving

the main cylinder for each leaf, each one of these strands describing a separate arc to the point where it enters a leaf base. Furthermore, all girdles are reported as being horizontal throughout their whole extent. It is obvious, therefore, that the phenomenon of girdling, as I have been able to trace it very distinctly and definitely in cleared specimens of two-, three-, and ten-year-old seedlings of *D. spinulosum*, differs in many respects from these earlier accounts. Thus for each leaf or scale leaf 7–9 strands, the number varying with the size of the sheathing leaf base, separate from the vascular cylinder. Two of these (fig. 8 *e*, e^1) leave the cylinder on the same side as the leaf for which they are destined and take an upward, oblique course for some distance, finally passing out more or less directly through the cortex into the ventral part of the petiole.

Two other traces (fig. 9 *a*, a^1) leave the main stele at closely approximated points on the side opposite the leaf for which they are destined and pursue an upward, rather oblique course for some distance. Then, curving one in either direction, they take a horizontal course, describing wide arcs through the cortex and sheathing leaf base, finally entering the dorsal or adaxial part of the petiole, where they undergo a complicated system of branching. The rest of the traces destined for this leaf (fig. 9 *b*, b^1, *c*, c^1, etc.) leave the main stele at intermediate points and assume, like traces (*a*, a^1), an upward, vertical direction, finally anastomosing with the two horizontal strands as they encircle the cortex. It is also noteworthy that each of these lateral oblique traces leaves the stem cylinder at a point slightly higher than the one preceding, so that the entire course of the two girdles is gradually and spirally ascending to the point where they enter the central part of the leaf base. Frequently a single bundle (fig. 8 *a*), separating from the vascular cylinder on the side opposite the leaf for which it is destined, may divide soon after leaving the central cylinder, the two horizontal branches swinging to right and left in wide curves through the cortex and the sheathing base of the leaf, and gradually anastomosing with the rest of the traces destined for that leaf. The character of the branching of these two main strands after entering the adaxial part of the petiole is so clearly illustrated in fig. 10 that any further discussion of this point is unnecessary.

At the very tip of the stem the traces of the youngest leaves ascend in an almost perpendicular direction about the region of the so-called potential vascular tissue to the point where they connect with the horizontal bundles. At this stage (fig. 10) all of the girdling strands lie in substantially the same plane, the pair associated with the youngest leaf describing slightly smaller arcs than those of the older leaves of the same crown. As internal radial growth and the appearance of new leaves crowd the older parts farther and farther away from their original terminal position, however, the lateral foliar traces become less vertical and more oblique. With this radial and longitudinal expansion of the stem is also associated a lengthening of the horizontal girdling strands, and consequently a widening of the intervals and the arcs between each lateral connecting trace.

These leaf traces are always endarch and collateral as they leave the stem cylinder, and also during their passage vertically and horizontally through the cortex to a point well up in the leaf base. They are so orientated that the xylem and phloem are directed toward the inside and the outside of the stem respectively. Transverse and longitudinal views (fig. 12) throw additional light on the organization of these cortical bundles.

COURSE OF LEAF TRACE IN ADULT STEM.—Due to the difficulties involved in following up strands of such size, it is impossible to determine with certainty whether the arrangement of the leaf traces in the adult stem of *D. spinulosum* is the same as that found characteristic of the seedlings. The problem becomes increasingly difficult as the plant reaches an age when the crown comprises numerous developing leaves. From longitudinal and transverse sections of the adult stem, however, it is evident that the same general relation between lateral oblique traces and a horizontal girdling strand is maintained, but it is probable that the girdling is only partial, that traces *a* and a^1 (fig. 9) would have their origin at points more remote from each other in the adult stem. It is also probable that there is no appreciable increase in the number of traces associated with successive leaves, beyond the number described as supplying the leaves of the ten-year-old seedling (fig. 10).

Discussion

In his description of the girdling habit, METTENIUS (10) finds that "in the developmental stage the traces of the youngest leaves

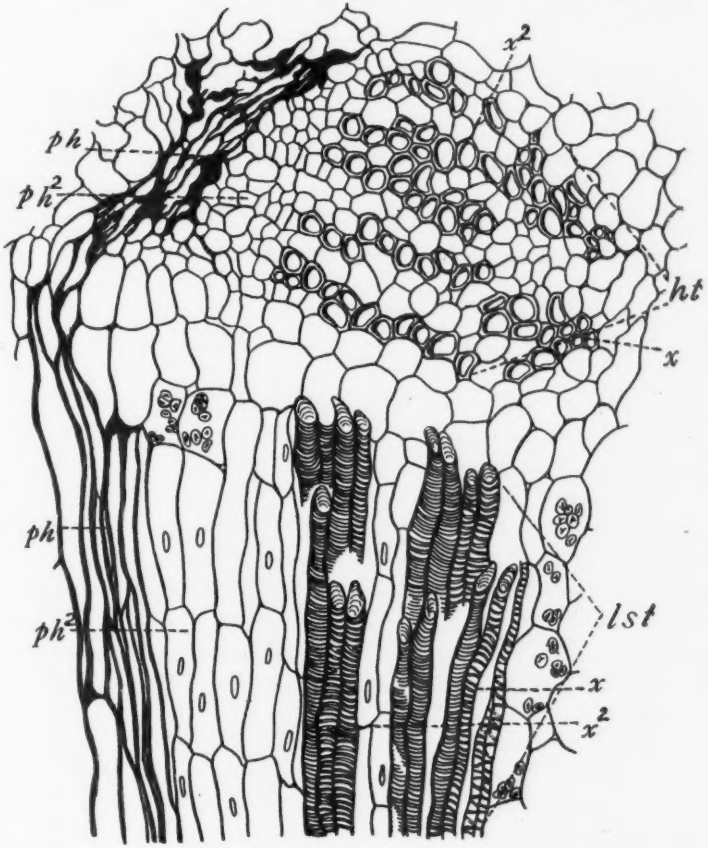


FIG. 12.—Detail of organization of cortical foliar strands of three-year-old plant: *ht*, horizontal strand in transverse section; *lst*, longitudinal section of vertical lateral trace near point of union with horizontal strand; *x*, primary sylem; x^2, secondary xylem; *ph*, primary phloem; ph^2, secondary phloem; ×120.

lie in the region of the vegetative point, and at first ascend in an almost perpendicular direction, but during further growth assume

gradually a horizontal position, and with subsequent growth are lengthened and the expanse increased." MATTE (9) and Sister HELEN ANGELA (3), in connection with *Ceratozamia*, both describe a similar vertical position of traces in the early developmental stages, girdling becoming evident with the increase in diameter of the inclosed group of leaves and stem. In more recent investigations of *Dioon edule* by THIESSEN, and of *D. spinulosum* by Sister HELEN ANGELA (4), however, both authors maintain that the girdles are established very early, and that their horizontal course is laid down from the beginning.

The results of the present investigation indicate two possibilities therefore. Either the arrangement of cortical strands in the older seedlings and adult wood of *Dioon spinulosum* differs from that found in the embryo and very young seedlings of both species of *Dioon*, or the preceding statements need considerable modification.

At the very tips of the two-, three-, and ten-year-old seedlings (fig. 10) the perpendicular arrangement of the lateral strands and their connection with the horizontal girdles is unmistakable. It is reasonable to suppose, therefore, that the arrangement of foliar strands in the first leaves of the young seedling would be substantially the same as that characterizing the leaves of the older seedlings, save that (1) the very young strands having their origin in the cotyledonary plate would ascend vertically for a shorter distance before anastomosing to form the horizontal girdles, and (2) there would be likely to be a decrease in the number of strands leaving the vascular plate for each leaf base.

Another question of importance is the significant relationship suggested by the distribution of leaf traces in the seedlings of *D. spinulosum*. Thus we find numerous strands (varying from 7 to 9) passing obliquely upward into each leaf base, each one of which causes a gap of its own in the main stele. As previously indicated, however, these strands do not all enter the petiole. There is instead an anastomosis of traces in the sheathing base of the leaf, resulting in the conspicuous and characteristic horizontal girdles, which correspond in many respects to the marginal vein of

the sheathing monocotyl leaves, save that the marginal vein of the typically sheathing monocotyl leaf is connected with a large number of bundles which come off around the entire periphery of the stem.

Summary

1. The medullary rays of *Dioon spinulosum* are of three distinct types: uniseriate rays, a single layer of cells wide and several cells deep; multiseriate rays, two to several cells in width and of variable longitudinal extent; and broad foliar rays or leaf gaps, which, with their included leaf traces, are such a constant feature of this wood.

2. The fibrovascular elements constituting the leaf traces in the foliar rays and connecting these traces with the secondary wood are peculiar, irregular scalariform tracheids which in the course of their development curve gradually downward through the ray, until they become inserted between the perpendicular fibrous elements of the main stele.

3. The regular pitted elements of the secondary xylem are also often diverted to one side into a direction parallel to that of the trace.

4. Both the scalariform and the pitted elements constituting these traces, in their peculiar manner of enlargement and elongation, furnish excellent illustrations of gliding growth.

5. For each leaf or scale leaf 7–9 strands (the number varying with the size of the leaf base) separate from the vascular cylinder. The two inner ones, arising from the proximal side of the central cylinder, pursue a more or less direct vertical course into the ventral part of the petiole; the rest of the traces, leaving the stem cylinder at different points, pass obliquely upward into the cortex and the sheathing base of the leaf, where an anastomosis of traces takes place, resulting in the two characteristic girdles.

6. The two direct strands entering the ventral or abaxial part of the leaf may also unite with the two dorsal girdling strands at the base of the petiole, so that the whole system is reducible in the older seedlings and adult stem to two main horizontal strands with their associated lateral traces.

Grateful acknowledgment is made of the helpful criticism and advice given by Professors JOHN M. COULTER, CHARLES J. CHAMBERLAIN, and W. J. G. LAND during the progress of the investigation. The writer is also greatly indebted to Dr. CHAMBERLAIN for the very generous supply of material.

GOUCHER COLLEGE
BALTIMORE, MD.

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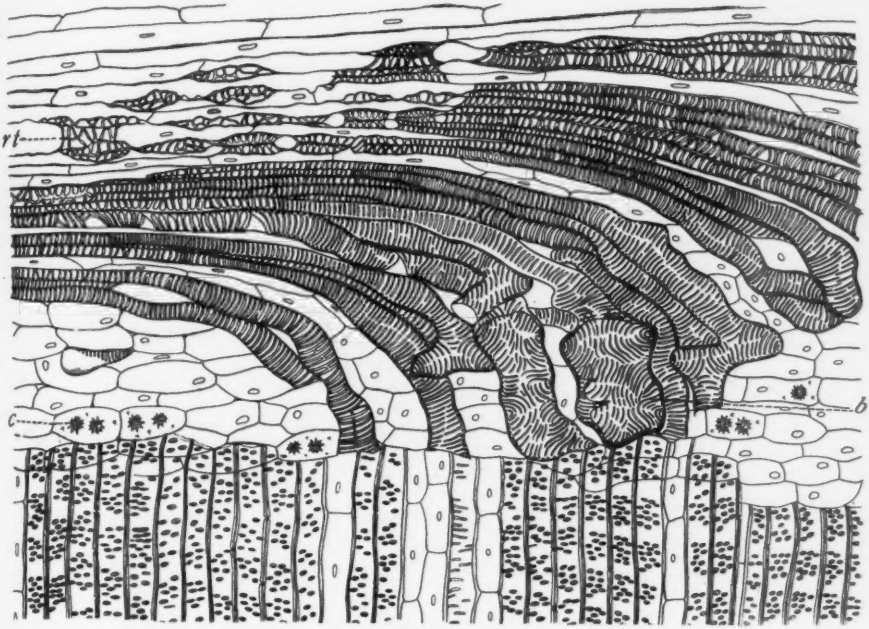
EXPLANATION OF PLATES XV–XVII

All the drawings were made with the aid of a camera lucida, except figs. 8, 9, 10, 11, which are diagrams showing origin and distribution of foliar vascular strands, as traced from cleared material, supplemented, where detail in connection was required, by serial sections; figs. 1–3 and 12 are in the text.

PLATE XV

FIG. 4.—Mature wood: radial longitudinal section of large foliar ray, showing organization of leaf trace and structure of scalariform tracheids of trace: *b*, bulbous bases of tracheids; *c*, calcium oxalate crystals; ×90.



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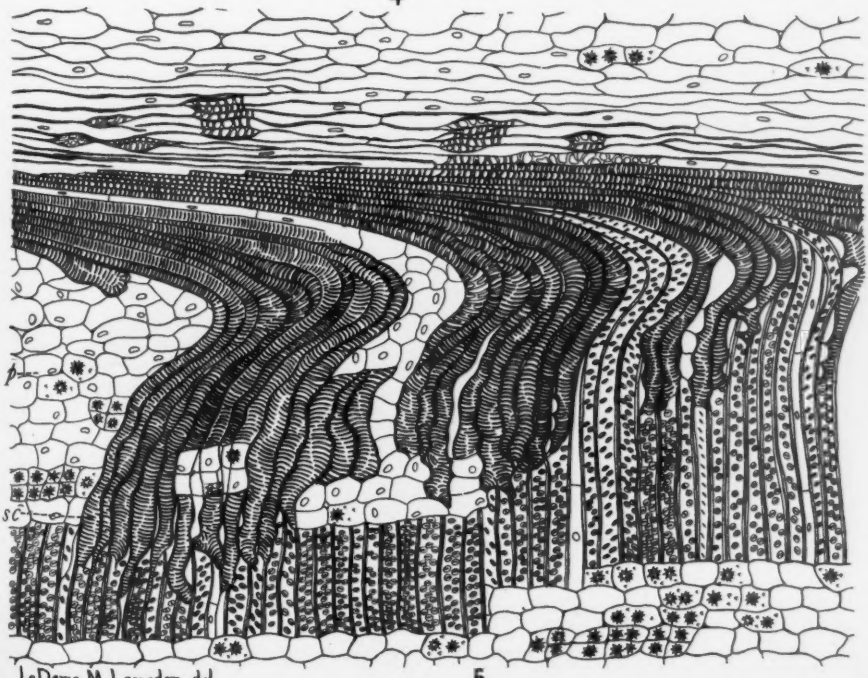

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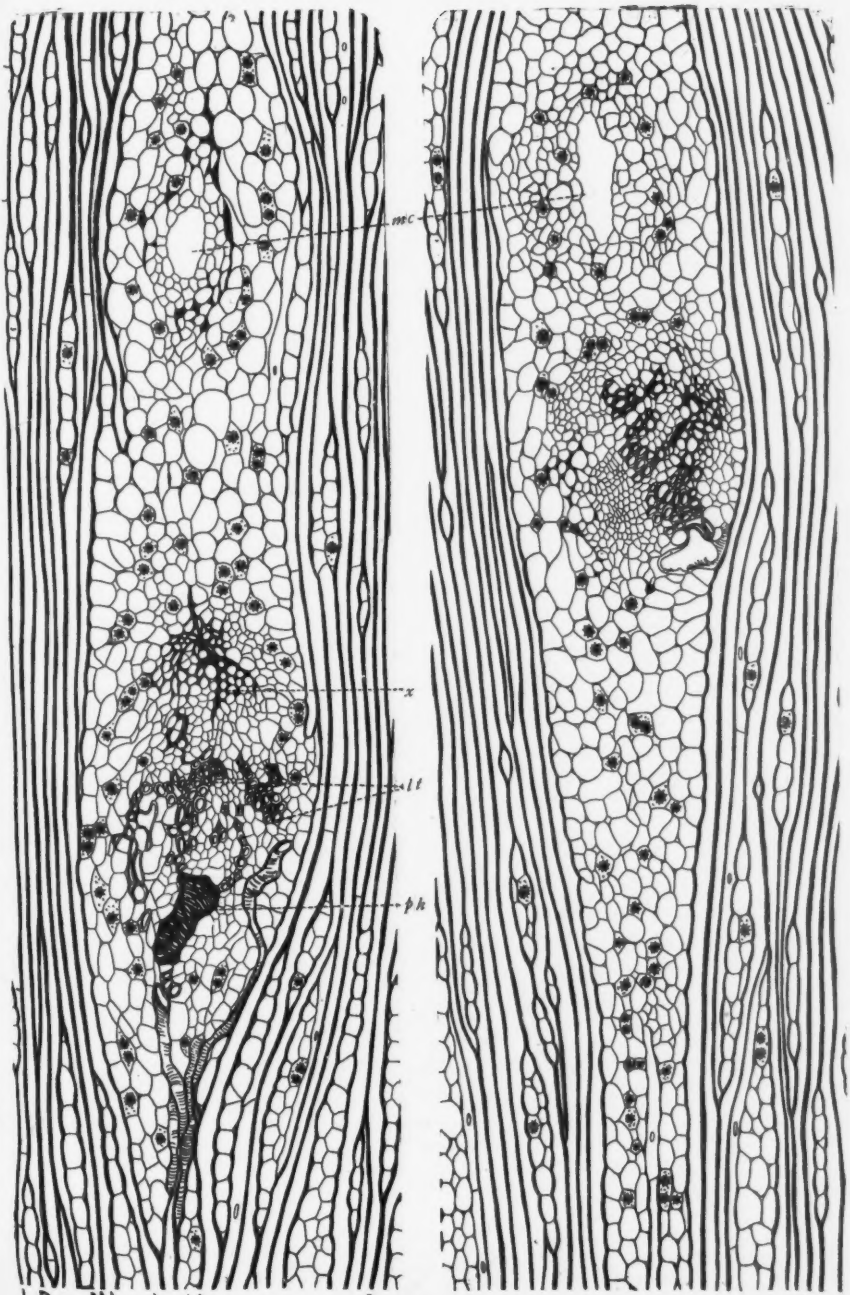
LANGDON on DIOON



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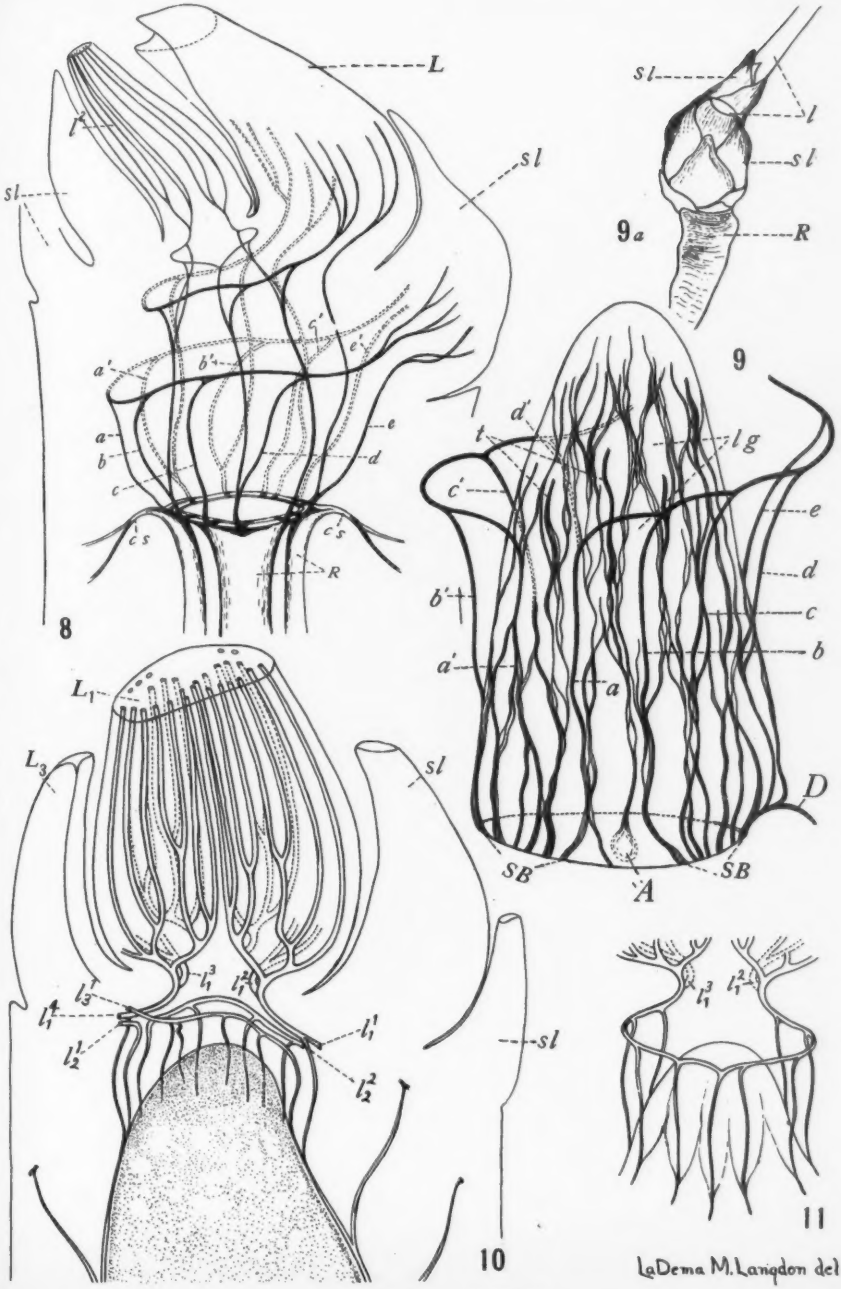

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FIG. 5.—Mature wood: radial longitudinal section near lateral border of leaf gap or foliar ray; *p*, pitted tracheids of secondary wood diverted to one side into direction parallel to that of trace; *sc*, scalariform tracheids of trace extending down between fibrous elements of main stele; ×55.

PLATE XVI

FIG. 6.—Mature wood: tangential section of foliar ray; *lt*, leaf trace, scalariform tracheids of trace seen in both longitudinal and transverse section; *x*, primary wood; *ph*, disorganized phloem; *mc*, mucilage duct; ×56.

FIG. 7.—Adult wood: tangential view of foliar ray in vicinity of cambium, tracheids constituting trace seen only in transverse section; ×56.

PLATE XVII

FIG. 8.—Two-year-old seedling, diagram showing: *sl*, origin and course of vascular supply of one of first scale leaves; *L*, first year foliage leaf, and l^2 second year foliage leaf, as traced from cleared material; *a*, a^1, *b*, b^1, *c*, c^1, etc., traces of scale leaf; *cs*, cotyledonary strands; *R*, vascular system of root; ×4.

FIG. 9.—Three-year-old seedling: diagram showing connection of lateral traces, *a*, a^1, *b*, b^1, *c*, c^1, *d*, d^1, and *e*, with stem cylinder, and manner of anastomosis to form horizontal girdles; *A*, *D*, two of the four main cotyledonary bundles; *S*, *B*, two of the four principal groups of stem bundles; *lg*, leaf gaps corresponding to foliar gaps of adult stele illustrated in figs. 6, 7; ×4.5.

FIG. 9*a*.—Three-year-old seedling; ×0.5.

FIG. 10.—Median longitudinal section through apical portion of ten-year-old plant, showing only one side of the three sets of horizontal girdles with their associated lateral vertical strands; L_1, L_2, L_3, first, second, and third leaves of crown; second leaf not shown and only part of third leaf; l_1^1, l_1^4, horizontal strands entering adaxial part of leaf one; l_1^2, l_1^3, ventral strands apparently united with the two dorsal girdling strands l_1^1 and l_1^4; ×2.5.

FIG. 11.—Diagram of entire vascular supply of first leaf, L_1, fig. 10; complete anastomosis of leaf traces to form one main horizontal girdling strand; ×2.5.

AUXOGRAPHIC MEASUREMENT OF SWELLING OF BIOCOLLOIDS AND OF PLANTS

D. T. MacDougal

(WITH TWO FIGURES)

The chief purpose of this article is to describe the methods which have been used in the study of colloidal preparations, the reactions of which might furnish a physical basis for the interpretation of growth in plants, and to recapitulate some of the features of swelling of these substances as yet undescribed or but little known.

The investigation of growth in plants involves a measurement of the unsatisfied hydration capacity of living cell masses, and also determinations of the total swelling capacity of desiccated material. In both cases the minute masses of colloids constituting the protoplasts are inclosed in thin walls with a low stretching coefficient. Furthermore, the living cells are in a condition of varying turgidity, dependent upon the osmotic activity of the vacuolar solutions, upon the permeability of the external layer of the protoplasm, and also upon the structure of the walls. Desiccated cell masses have lost the capacity of turgidity as ordinarily known, but may still show some osmotic activity by the differential action of the dead wall (as may other colloids), while the protoplasts have undergone changes due to the action of salts and acids in the concentration of cell saps which accompanies desiccation.

It is not possible to reproduce the mechanical structure of cell masses by artificially compounded biocolloids, so the experimenter must be content to ascertain the general composition of the protoplasm, bring the main constituents together in the form of a jelly, dry this to thin plates, and measure the action of sections of it in solutions of a kind and concentration which would give effects similar to those encountered in living matter.

Physiologists concerned with life in animals dealing with a protoplasm consisting chiefly of proteins and lipins with a characteristic metabolism, have found in gelatine and in the soaps material

which furnishes many valuable homologies. These are in imminent danger of being overworked, however. Not only has gelatine been taken to simulate protoplasm in general, but physicists have committed a similar error of taking the behavior of gelatine as universal for colloids.

Not much progress had been made in the attempt to determine the physical basis of growth in plants before it became plainly obvious that the relations of plant protoplasm to H ion concentration, acidity, temperature, and other conditions diverged widely or were directly the reverse of the action of gelatine.

In seeking other material in a colloidal state which might by its hydration, swelling coefficient, etc., simulate the plant, recourse was had to actual analyses of plants as made in connection with studies in desiccation, starvation, etiolation, and as part of the work on the carbohydrate metabolism of plants by SPOEHR.[1]

The possible importance of the pentoses as a factor in the mechanism of hydration and growth was evident at once. A knowledge of the manner of formation and occurrence of these sugars and of their condensation products, the pentosans (mucilages, slimes, gums, etc.), is necessary in order to understand the rôle they play in the cell.

The metabolism of the plant is predominantly carbohydrate, and the protoplasm may be taken to contain solutions of sugars at all times. Included among the numerous possible changes, it is known that in the depletion of the water content of a plasmatic mass by a general loss from the cell, or by lowered hydration capacity of the colloid by the action of any agent, polysaccharides which have but little imbibition or hydration capacity are reduced to pentosans or mucilages which have a relatively enormous capacity for taking up water. Dextrose, starch, wall material, etc., may be involved in these conversions, and, when masses of material are affected, layers or globules of mucilage may be formed which may react to microchemical tests. It is noted, however, that visible masses of mucilage are of less importance in the mechanism

[1] SPOEHR, H. A., Carbohydrate economy of the cacti. Publ. no. 287. Carnegie Inst. Wash., p. 44.

———, The pentose sugars in plant metabolism. Plant World 20:365. 1918.

of the cell. The pentosans play their most important part when they are in the form of minute particles in the colloidal mesh of living matter, in which they are still subject to positive but slow changes in metabolism. According to MACDOUGAL, RICHARDS, and SPOEHR,[2] the conversion of other sugars into the pentosans, greatly increasing the hydration capacity of the protoplasm, is the basis of the origination of the xerophytic and succulent types of vegetation.

These facts warrant a procedure in the study of swelling and growth in which various pentosans and pentosan-protein mixtures were subjected to the action of solutions, applied in a concentration and with variations and alternations parallel to occurrences in the cell.

The method of measuring the water capacity of colloidal material includes the following features:

1. Suitable solutions or suspensions are poured at temperatures of 30 to 40° C. into shallow molds to form a jelly.

2. The plates thus cast are dried in a small chamber with a high relative humidity, to a thickness of 0.1 to 0.25 mm.

3. Trios of sections 3×5 mm. in area are placed in dishes of a capacity of 30 cc., a triangular piece of thin glass is placed over the sections, and the vertical swinging arm of an auxograph is seated in the center of the glass. Any change in thickness of the sections moves the levers and moves a pen on a recording sheet carried by the drum.

4. Solutions, the effect of which on the hydration capacity of the sections are to be tested, are poured into the dishes. In nearly all of the experiments in the special range of biological relations it is advisable to renew or replace the solutions at certain intervals.

5. Temperature relations are of the greatest importance, and the record is taken by mercurial thermometers, the bulbs of which are in dishes of liquid similar to those of the experiment.

[2] MACDOUGAL, D. T., and SPOEHR, H. A., The origination of xerophytism. Plant World 21:245. 1919.

MACDOUGAL, D. T., RICHARDS, H. M., and SPOEHR, H. A., The basis of succulence in plants. BOT. GAZ. 67:405. 1919.

6. Every measurement obtained by this method is an average of the action of three sections, and has the value of an average. Any value showing notable departures from expectancy should be repeated.

7. Measurements of the swelling of sections by the auxograph give variations in thickness, and serve as direct indices of total changes in volume in plates of agar and agar mixtures, as this material has a strict tendency to return to its original form. Sections of gelatine swell in all dimensions no matter how the plates are cast.

It was desirable to use the best known and most available pentosans or hemicelluloses, and agar-agar, acacia gum, tragacanth, mesquite gum, cherry gum, and mucilage of *Opuntia* were selected for the tests. According to information furnished by H. NAKANO of the Botanical Garden of Tokyo, agar is prepared chiefly from the algae *Gelidium amansii* Lamour, *G. pacificum* Okam, *G. linoides* Kütz., and *Pterocladia capillacea* Born. et Thur., while some material of *Gelidium subcostatum* Kütz., *Ceramium Boydenii* Gepp., *Campylaephora hypenaloides* Y. Ag., and *Acanthopeltis japonica* Okam, etc., may be included. The process includes washing in fresh water, decoloration in the sun, milling, boiling, filtering, maceration in sulphuric or acetic acid, freezing, and drying. Modernized methods simplify this treatment somewhat. Salts, amino-acids, etc., may be present in the final product, and, as it was desirable to reduce the amount of all such subtances, the interest of E. R. Squibb and Sons was obtained, and a purified product was made by the following procedure.[3]

A good grade of commercial agar was dissolved in distilled water and jacketed with superheated steam. The viscous solution produced thereby was filtered clear through a thick mass of steam-jacketed paper pulp, under diminished pressure. The clear solution of agar was dialyzed for about 10 days in a steam-jacketed bath containing running distilled water. After removal of diffusible carbohydrates and salts by the dialysis through parchment paper

[3] For further information concerning the origin and preparation of similar products see SWARTZ, M. D., Nutrition investigations on the lichens, algae, and related substances. Trans. Conn. Acad. Arts and Sci. 16:247–382. 1911.

of the quality usually employed in the serum industry, the clear solution was slowly poured in a fine stream or spray into 10 times its volume of neutral acetone. The agar was precipitated in the form of fine shreds. It was subsequently extracted with hot absolute acetone, absolute alcohol, and absolute ether. The final product was ground to a granular powder in a porcelain ball-mill with porcelain balls. The resulting preparation contains only a trace of nitrogen and a trace of ash.[4]

Samples of this agar made up as a 2.5 per cent solution with distilled water had a light brown tinge, dissolving completely within an hour at about 100° C. It was found that the material made up as a 0.75 per cent solution, when poured into a test-tube, formed a "slant" which kept in place when the tube was set in an upright position at 15° C. for 2 weeks. Layers 1 cm. deep in small flasks retained their form when the flasks were inverted in some instances. Some water was separated, gathering on the upper part of the tube or flask, and the appearance of same on the surface of the agar suggested syneresis. Tests of this agar by the colorimetric process of DUGGAR gave it a hydrogen ion concentration denoted by $P_H = 6.5$.

The mucilage of *Opuntia*, cherry gum, mesquite gum, *Acacia*, and tragacanth gum was extracted or dissolved in water (nearly always showing a solid residue), precipitated with alcohol, filtered, and dried in a desiccator. These substances go into solution at lower temperatures than agar, and differ from it in many important features, as may be seen in the table of swelling reactions.

Special preparations were also made of salt-free water-soluble albumins from oats, wheat, the common bean, soy bean, and castor bean, as well as of lipins and amino compounds, by methods commonly used and need not be described here. The gelatine used was the "bacto-gelatine" now available in quantity.

The measurement of the swelling of these colloids must take into account the structural features resulting from dehydration. Sections or plates of agar, for example, tend to return to the form and dimensions of the layer of watery gel from which they were produced. This is not true of gelatine, as will be described later,

[4] The description of this process was furnished by Dr. ISAAC HARRIS.

nor can it be said of the other mucilages or gums already mentioned as they go into solution from the surfaces of the sections; but sections in which agar forms as much as half may be assumed to return to the original in nearly all work, with a change of not more than 2–5 per cent in area (fig. 1).

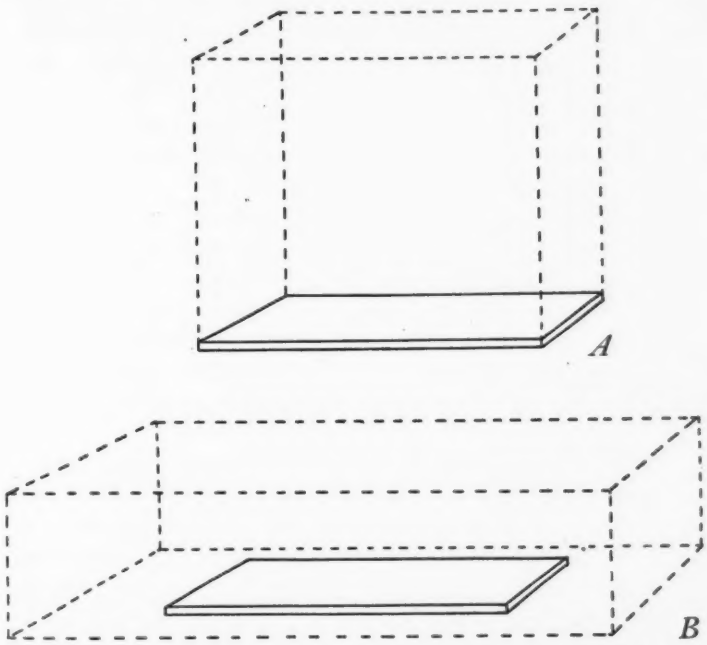

FIG. 1.—Diagrams illustrating action of dried plates of agar and gelatine in swelling: in *A*, section of agar, represented by thin plate forming bottom of figure, swells to larger block by increase almost wholly in thickness; in *B*, gelatine plate represented by small inner figure increases not only in thickness but also in length and breadth to form larger block of jelly.

In view of these facts, it is evidently desirable to cast plates and dry sections in such manner that the dried sheet of material will have the areal dimensions of the original, and that all of its shrinkage will have taken place in such manner as to reduce the thickness only. The preparation of such plates may be done simply by pouring warm solution on a glass plate, where it hardens,

dries, and adheres. If it does adhere in such manner as to prevent areal shrinkage, it generally is to be removed with difficulty and may be destroyed in the process.

An improved method of making such plates is briefly as follows. First a sheet of gold foil is laid out on a leveled glass plate on a table. Blocks of glass or of some non-corrosive metal are placed on the margins of the gold. The warm agar is poured into this cell in a 2.5 per cent solution, at 40° C., and in cooling to 18 or 20° C. it sets, and the blocks may be removed. The gel now stands on a base of gold foil, and unless anchored at the margins will shrink in all dimensions as it dries, a thing which specifically is to be prevented. To do this a little warm solution of agar is run around the agar plates which on cooling cements the margin to the glass. The preparation is now set in a dehydrating chamber with a humid atmosphere and subjected to the action of an electric fan for 40 hours. At the end of this time it has come down to a plate about one-fortieth of its original thickness, and may be detached from the plate by cutting away the marginal portion. Properly made, such plates are even as to thickness and swelling qualities.

When albumin, gelatine, or other albuminous substances are to be mixed with the agar, the solution of the latter is cooled to 40° C., and then the other substances in a liquefied condition are poured in and stirred for a few minutes before the plate is poured, which should be done at about 35° C.

The process puts the experimenter in possession of a sheet of dried material, preferably between 0.15 and 0.20 mm. in thickness, and after the margins are trimmed away with the scissors the sheet will probably have a surface of about 7×12 cm. As indicated, these sections may be about 3×5×0.16 mm., with a volume of 2.4 cu. mm., and the trio in a dish have a total of 7+cu. mm., into which a measured amount of solution is poured and replaced as the experiment demands. If thinner sections are used, their area should be reduced.

The auxograph consists essentially of a compound lever set with a vertical swinging arm which rests on the triangular glass plate covering the sections in the dish, and its use in measuring

the swellings is a means of recording phenomena not to be evaluated in any other manner[5] (fig. 2).

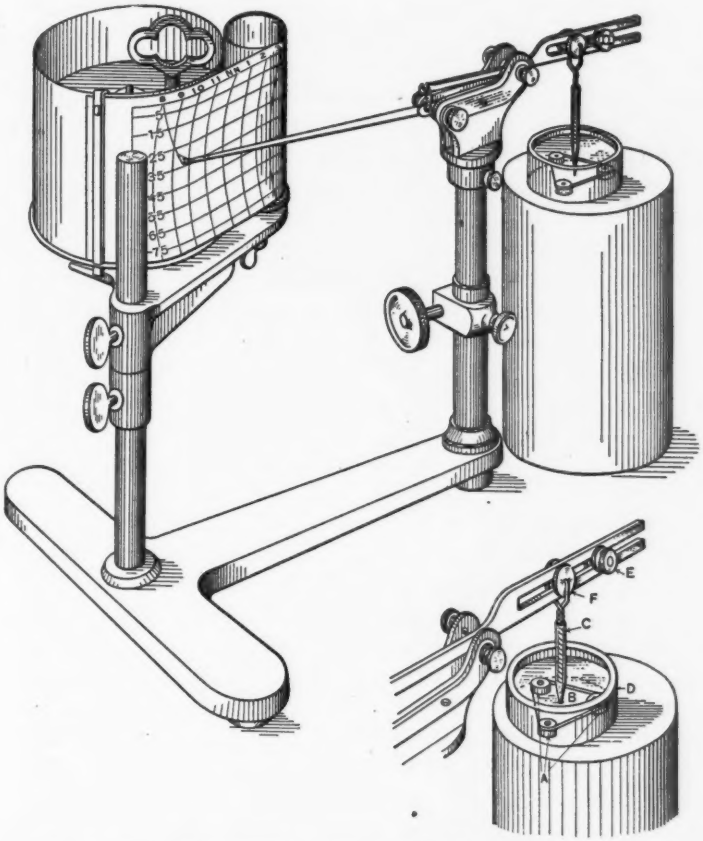

FIG. 2.—Auxograph arranged to record changes in thickness of trio of sections of colloidal material; tip of pointed glass tube, sealed to vertical swinging arm *C* (smaller figure), rests in socket in center of thin triangular glass plate *B*, which lies on sections *A;* expansion of sections pushes this arm upward (adjustment at *F* placed to give an amplification of 20 in cut), compound lever being arranged to give a downward movement of pen; record slip, daily or weekly, 8 cm. wide, is ruled to mm. (not shown in cut). Illustration made to show action of trio of sections of agar in water at end of 1.5 hours.

[5] For description of this apparatus see MACDOUGAL, D. T., Hydration and growth. Publ. no. 297. Carnegie Inst. Wash. 1919.

Thus, for example, instead of the common method of taking the total gross volume of a colloid in a dish or test-tube, the auxograph calibrates the action of sections like those of agar, which swell almost wholly in one axis (and a related heterotropic swelling is highly probable in all protoplastic action), and records the continuous rate of swelling. This gives the experimenter exact information on many features, of which the practical cessation of swelling is one of the most important. Thus some of the records show a swelling at a decreasing but notable rate for as long as 20 days. The termination of the experiment at the end of the second or even the tenth day would have eliminated some of the most striking and important features of the reaction.

Such continuous records are also necessary in following the action of solutions in which the mass relations are such as to require renewal of the liquids, and in the study of plates in which amino compounds, salts, etc., have been incorporated. Of other features, by no means the least advantageous is the use of the same instrument in measuring changes in volume by growth swelling of living and dried cell masses of plants.

A set of results of swelling of various biocolloids is given in table I, in which the increases, first obtained in percentages of the original thickness of the dried material, are converted into figures relative to the swelling in water which is taken as 100.

The P_H values were calculated from colorimetric tests after the indicator method perfected by DUGGAR,[6] soy albumin showing a value of 6.2 in a 0.5 per cent solution, *Opuntia* mucilage 5.8 in a 1 per cent solution, cherry gum 5.1 in a 1 per cent solution, acacia gum 5.1 in a 1 per cent solution, and gelatine 5.2 in an 8 per cent solution.

These biocolloids are to be regarded as intimately mixed particles, strands, webs, or globules of pentosans and of proteins, as these substances do not unite and are not mutually interdiffusible. The combinations of material were so arranged as to

[6] DUGGAR, B. M., and DODGE, C. W., The use of the colorimeter in the indicator method of H ion determination with biological fluids. Ann. Mo. Bot. Gard. **6**:61–70. 1919.

DUGGAR, B. M., Refinements in the indicator method of hydrogen ion determination. Rept. Dept. Bot. Research, Carnegie Inst. Wash. 1919.

give illustration of the special character or dissimilarity of constitution of these mucilages when used to replace part of the agar. First it is to be seen that in the biocolloids in which acacia, cherry, and mesquite gum replace one another, the reactions to high H ion concentration in the acid and to potassium hydroxide are not widely different in total amount. The coefficient of increase in

TABLE I

RELATIVE SWELLING OF BIOCOLLOIDS IN ACIDS, HYDROXIDES, SALTS, AND WATER AT 15° IN 0.01 N CONCENTRATION; INCREASE IN WATER GIVEN IN PERCENTAGES OF ORIGINAL DRIED THICKNESS OR VOLUME

Material	Parts	KOH	NH_4OH	KNO_3	HNO_3	HCl	Water
	P_H	11.99	10.61	6.6	2.01	2.01	
Agar	10	33	83	39	44	44	(1800)
Gelatine	10	200	197	80	245	300	(1570)
Agar	8	50	45	45	32	23	(2000)
Soy bean albumin	2						
Agar	4	19	25	47	22	22	(2785)
Opuntia mucilage	4						
Soy bean albumin	2						
Agar	4	29	41	58	26	28	(2415)
Cherry gum	4						
Soy bean albumin	2						
Agar	4	33	36	67	31	29	(2100)
Acacia	4						
Soy bean albumin	2						
Agar	4	110	91	96	48	48	(1100)
Acacia	4						
Gelatine	2						
Agar	3	75	90	67	50	56	(1200)
Acacia	3						
Soy bean albumin	2						
Gelatine	2						

potassium nitrate does vary widely, however. The special effects in ammonium hydroxide are discussed elsewhere.[7]

When these mixtures are viewed as homologues of cell masses or of plant protoplasm, that containing the *Opuntia* mucilage

[7] MACDOUGAL, D. T., and SPOEHR, H. A., The effect of organic acids and their amino compounds on the hydration of agar and on a biocolloid. Proc. Soc. Exper. Biol. and Med. **16**:33. 1919.

assumes a special interest, as the total swelling in water is greatest of all of the combinations, and the depressing effects of acid, hydroxide, and salt are very marked. These features would be characteristic of a plant capable of a wide range of water content and sensitive to changes in the sap, as is known to be the case from studies of the growth of *Opuntia*.

The substitution of gelatine for albumin, or its addition to a mixture increases swelling in acid, salt, and hydroxide as would be expected, and lessens the total swelling in water. These and other available data may be profitably construed in many directions in the interpretation of growth phenomena.

The methods of preparation and measurement of swelling of colloids described have served to confirm and extend knowledge of the behavior of agar, albumin, gelatine, and of mucilages, and to fix upon pentosan-protein mixtures which swell in a manner similar to cell masses of plants. The use of the auxograph has made it possible to compare the nature, extent, and duration of these changes with variations in volume of growing cell masses.

The casting and desiccation of colloidal plates in such manner that shrinkage and swelling takes place unequally in different axes, and the measurement of such differential swelling also furnishes some evidence which may be of value in interpreting the changes in form, etc., of the special bodies of the protoplast which accompany and mark the morphological crises of the cell.

DESERT LABORATORY
TUCSON, ARIZ.

HAWAII'S TAPESTRY FORESTS

VAUGHAN MACCAUGHEY

(WITH SIX FIGURES)

Many of the Hawaiian mountains are deeply eroded. Torrential rainfalls, operating throughout vast periods of time, have strongly carved the original volcanic domes. Extraordinary precipices (called *pali* by the natives) abound in all parts of the islands. Fantastically sculptured canyons, ravines, and gorges, profusely cliffed and ramified, are characteristic of the montane areas. The valley walls are notably abrupt. Many of the valley heads are rimmed with cliffs and crags. The summit ridge on such islands as Kauai, Oahu, and Molokai is worn in many places to a thin crest, with numerous lateral "razorback" ridges.

Associated with this highly dissected topography is the subtropical montane rain forest. The general features of this forest have been presented by the writer in other papers.[1] Herein are described only those portions of the rain forest that cling to very steep slopes.

The naturalist, exploring the Hawaiian forests, is sure to be impressed by the ability of the groves to maintain themselves on very precipitous slopes. Although the individual trees are of small stature, with abundant shrubby undergrowth, all of the area is closely occupied, forming an unbroken arborescent or semi-arborescent mantle. The writer proposes the name "tapestry forest" for this particular forest type, that successfully occupies almost vertical mountain walls. All tapestry forest is montane rain forest, but all rain forest is not tapestry forest. Indeed, the most luxuriant rain forest is on gently sloping uplands (for example, Puna and Olaa, Hawaii); the trees of this *Metrosideros-Cibotium* formation attain heights of 75–90 ft. The tapestry groves of course do not grow on absolutely vertical cliffs. Seen from a

[1] Survey of the Hawaiian land flora. BOT. GAZ. 64:98–114. 1917; Oahu rain forest. Amer. Forestry 23:276–278. 1917; Economic woods of Hawaii. Forestry Quarterly 14:696–716. 1916.

distance, the slopes mantled with vegetation appear to be much steeper than they actually are. The actual slopes range between 40 and 80°, averaging 50–60°. The vertical walls are either totally bare, or, if somewhat roughened and ledgy, support a depauperate, windswept, scattering growth of hardy grasses, ferns, and bryophytes. The moist areas, produced by seepage waters, are habitats of algae, lichens, and mosses.

The finest examples of tapestry forest occur in the following situations. On the island of Kauai: the Na Pali district, Wainiha,

FIG. 1.—Tapestry forest on deeply eroded mountain ridges

Hanalei, and on the upper summit ridges and cliffs of Waialeale. On the island of Oahu: the windward precipices of the Koolau Range, and such valleys as Makaha, Makua, and Waianae, in the Waianae Range. On the island of Molokai: the precipices and summit slopes of such valleys as Halawa, Pelekunu, Wailau, and Kalawao. On the island of Maui: the valleys of Iao, Waikapu, Waihee, and the summit slopes of West Maui; also the windward and eastern valley slopes of East Maui. On the island of Hawaii: Waipio and Waimanu valleys, and other precipitous slopes along the Hamakua coast.

In altitudinal range the tapestry forests lie mostly between 800 and 4500 ft., in hygrophytic situations. In certain localities, as along the Hamakua coast, they extend to sea-level. In numerous situations along the Hawaiian coast are cliffs and low peaks, now arid and xerophytic, which give evidence of having been covered by tapestry rain forest in prehistoric times.

The steepness, wetness, and general inaccessibility of the tapestry groves have prevented wild cattle and goats from ravaging them. Thus they have been spared the devastations so

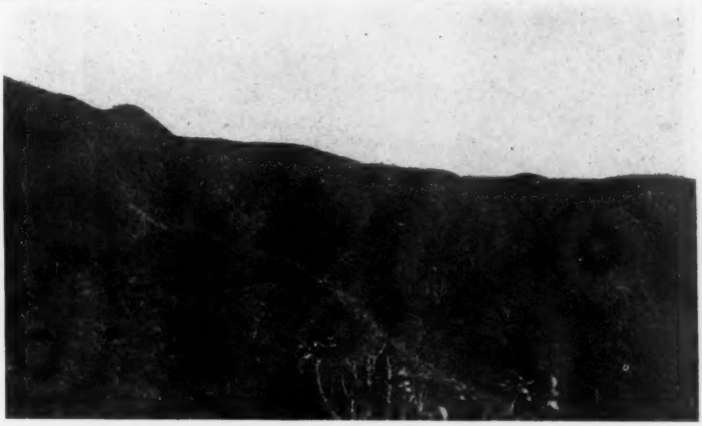

FIG. 2.—Oahu tapestry forest; montane rain forest

abundant and irreparable in the lower forests, and retain a much more primitive aspect. The undergrowth, although relatively scanty, and composed of smaller individuals than is the undergrowth of the lower forest, is particularly interesting because of its primitive and undisturbed character.

Closely related to the tapestry groves, both in ecological characters and in floral content, are the groves which inhabit the steep-walled hanging valleys, or high ravines, that are such a characteristic feature of the Hawaiian montane topography. These steep glens, lying at elevations of 800–3000 ft., do not terminate on the level of the valley floor into which their waters debouch, but on the face of

sheer cliffs, 100–2000 ft. high. The streams fall over these cliffs in beautiful cascades. The rain forest in the hanging valleys is not subjected to ecological conditions as severe as those of the tapestry forest, and hence attains more normal development.

The tapestry groves are notably dwarfed, with the aspect of marked and premature senility. The conditions of the substratum

FIG. 3.—Tapestry groves on very steep lateral spurs

afford but precarious roothold, and are obviously unfavorable for normal arborescent development. Many species that in sheltered level regions reach heights of 50–80 ft., with large trunks and symmetrical crowns, are stunted, gnarled, and dwarfed to a marked degree on the precipices. The trunk is short, usually leaning outward from the cliff, rarely erect, and breaks up into a number of

wind-shaped branches. Most of the steep slopes are subjected to strong winds, which impress their mark upon all aerial parts of the vegetation. Very young trees and old dead trees are alike rare in the tapestry groves, the area being so closely occupied by mature trees. Conditions are unfavorable for seedlings, and reproduction is conspicuously retarded. Weakened or dead trees soon lose their roothold, and fall from the grove into the lowlands below. The appearance of senility is in part fictitious, as none of the trees give

FIG. 4.—Tapestry groves on valley wall, Kalihi, Oahu

evidence of being more than 100–150 years old, and the younger trees (10–50 years) soon acquire an aged and decrepit appearance in their ceaseless struggle against gravity and wind.

The observer, standing on the floor of a valley and looking at the forest mantle which drapes the slopes, is impressed by the various shades of green in the mottled canopy. All of the tree crowns are domed or hemispherical; there are no conifers or cycads. Most of the crowns are more or less highly ramified. The foliage in the majority of cases is composed of small, simple, oval, glossy

leaves. Thus the summits or crowns of the various species look very much alike, save for the differences in the green tints. These

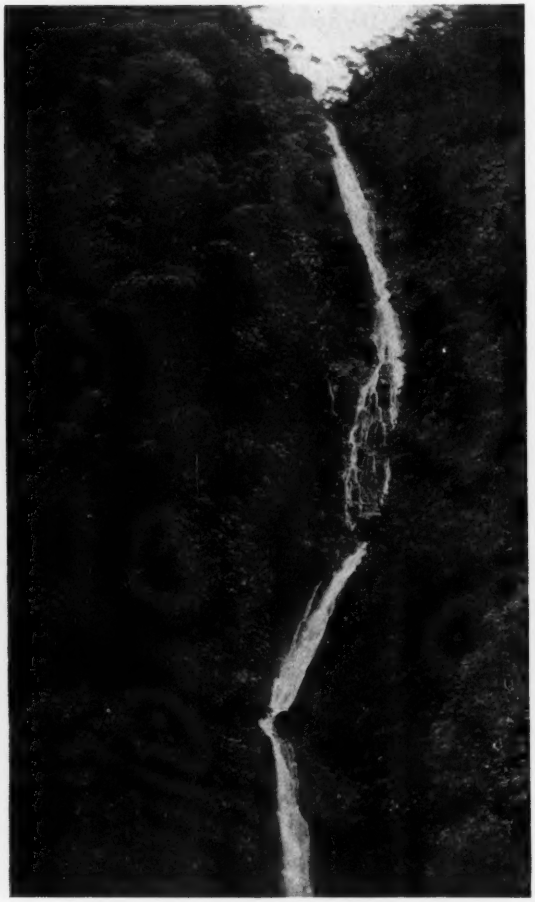

FIG. 5.—Vertical wall, with cascade and tapestry formation

differences are much more pronounced than in temperate zone forests, and give to the tapestry a distinctive and singular charm. Gray-green, yellow-green, olive-green, silver-green, green flushed

with red, heavy somber green, glossy green, literally scores of subtle and indefinable shades of green are discernible to the prac-

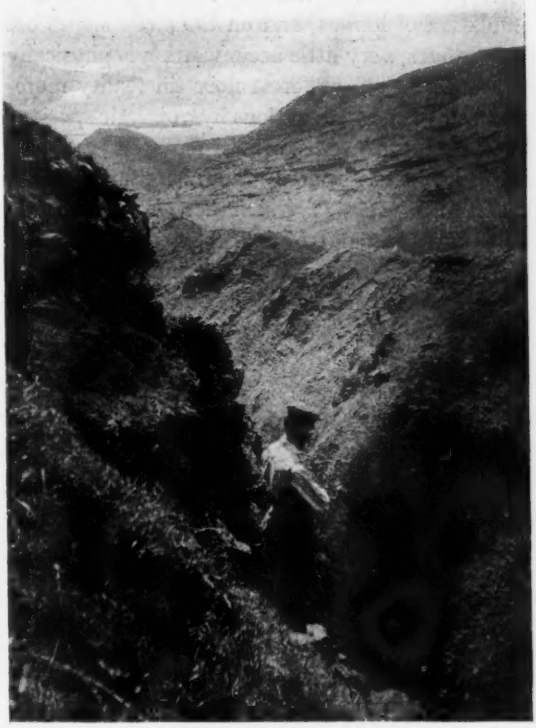

FIG. 6.—Arid ridges and precipices, formerly forested, devastated by goats and cattle

ticed eye. These varied hues give to the groves, particularly in the slant light of late afternoon, a rich, mottled, velvety effect, as though the forest were indeed a wondrous woven drapery.

A vertical or cross-section through a typical grove would reveal the following strata. (1) The basaltic rock cliff or wall, made up solely of ancient lava beds, piled one upon another. (2) A thin layer of lava soil, 4–12 inches thick, yellowish or reddish stiff clay, and excessively retentive of moisture. This soil is derived directly from the underlying lava. When stripped of vegetation, as by landslides, it washes away very rapidly, and exposes the rock strata. (3) A very thin layer of vegetable mold, not exceeding 2–6 inches. Conditions in the rain forests are not favorable for the accumulation of humus, and on the steep slopes occupied by the tapestry groves, very little accumulation is physically possible. (4) The vegetable mold or forest floor (in reality more of a wall than a floor) is covered with various hygrophytic species of lichens, liverworts, mosses, filmy ferns, coarser ferns, and a few herbaceous-perennial seed plants. Among the latter are such genera as *Astelia*, *Gunnera*, *Liparis*, *Peperomia*, *Nertera*, etc. (5) The forest proper, consisting of small trees, shrubby trees, shrubs, and lianas. The following are representative members of the Hawaiian tapestry grove formations:

Acacia koa Gray
Aleurites moluccana Willd.
Alyxia olivaeformis Gray
Antidesma platyphyllum Mann
Bobea elatior Gray
Broussaissia arguta Gaud.
Charpentiera ovata Gaud.
Cheirodendron Gaudichaudii Seem.
Cheirodendron platyphyllum Seem.
Claoxylon sandwicense Mueller
Clermontia spp.
Coprosma spp.
Coreopsis spp.
Delissea spp.
Dodonaea viscosa L.
Dubautia laxa Hook. and Arn.
Dubautia plantaginea Gaud.
Elaeocarpus bifidus Hook. and Arn.
Eugenia sandwicensis Gray
Euphorbia Hookeri Steud.
Euphorbia multiformis Hook. and Arn.
Euphorbia spp.
Eurya sandwicensis Gray
Exocarpus brachystachys Hbd.
Freycinetia Arnotti Gaud.
Gardenia Brighamii Mann
Gardenia Remyi Mann
Gouldia spp.
Hesperomannia arborescens Gray
Hibiscus Arnottianus Gray
Hibiscus kokio Hbd.
Ilex sandwicensis Loes.
Kadua spp.
Labordia spp.
Lipochaeta connata DC.
Lipochaeta decurrens Hbd.
Lipochaeta spp. and vars.
Lobelia spp.
Lysimachia Hillebrandia Hook. f.
Lysimachia spp.
Maba sandwicensis A.DC.
Metrosideros macropus Hook. and Arn.
Metrosideros polymorpha Gaud.

Metrosideros rugosa Gray
Metrosideros tremuloides Rock
Nothocestrum spp.
Ochrosia sandwicensis Gray
Osmanthus sandwicensis Knobl.
Osteomeles anthyllidifolia Lindl.
Pelea spp.
Perrottetia sandwicensis Gray
Phyllostegia spp.
Pipturus albidus Gray
Pisonia umbellifera Seem.
Pittosporum spp.
Plectronia odorata Benth. and Hook.
Platydesma campanulata Mann
Platydesma cornuta Hbd.
Pritchardia spp.
Rauwolfia sandwicensis A.DC.
Reynoldia sandwicensis Gray
Rollandia spp.
Santalum Freycinetianum Gaud.
Santalum spp.
Scaevola spp.
Scheidea spp.
Sideroxylon spp.
Smilax sandwicensis Kunth.
Solanum sandwicense Hook. and Arn.
Stenogyne spp.
Straussia spp.
Styphelia tameiameia F. Muell.
Suttonia spp.
Tetramolopium spp.
Tetraplasandra spp.
Urera sandwicensis Wedd.
Vaccinium penduliflorum Gaud.
Viola spp.
Viscum articulatum Burm. and vars.
Wikstroemia spp.
Xanthoxylum spp.

Among the ferns of the humid forests, the following are likely to occur in the tapestry groves:

Adiantum capillus-veneris L.
Asplenium spp.
Athyrium spp.
Botrychium subbifoliatum Brack.
Ceropteris spp.
Cibotium Chamissoi Kaulf.
Cibotium Menziesii Hook.
Cibotium glaucum Hook. and Arn.
Coniogramme spp.
Cyrtomium Boydiae Robins.
Dicranopteris spp.
Diellia pumila Brack.
Diellia falcata Brack.
Doodia Kunthiana Gaud.
Doryopteris spp.
Dryopteris spp.
Elaphoglossum spp.
Filix Douglassii Robins.
Hymenophyllum spp.
Hypolepis punctata Mett.
Lycopodium spp.
Marattia Douglassii Baker
Microlepis spp.
Neottopteris Nidus J. Sm.
Odontoloma Macraeanum Brack.
Ophioglossum pendulum L.
Pellaea ternifolia Link.
Phymatodes spp.
Polypodium spp.
Psilotum complanatum Sw.
Psilotum nudum Griseb.
Ptedium aquilinum Kuhn
Pteris cretica L.
Sadleria cyatheoides Kaulf.
Sadleria Hillebrandii Robins.
Sadleria polystichoides Heller
Sadleria spp.
Schizaea robusta Baker
Selaginella spp.
Tectaria cicutaria Robins.
Trichomanes spp.
Vittaria rigida Kaulf.

Of particular interest, from the ecological viewpoint, are the root systems of the tapestry grove trees and shrubs. The combination of steep declivity, thin clay soil, and rock substratum necessitates the development of an unusually strong mechanical root-supporting system. Most of the trees have a number (5–12) of large proplike roots which extend downward below the trees, and are firmly rooted in interstices in the ancient lava beds. These lower roots brace the tree staunchly from below. On the upper side of the trunk are usually several long anchoring roots, more or less exposed in the thin vegetable mold. The extremities of these roots are likewise rooted among the rock strata. In some situations, where the processes of erosion are gaining upon the grove, and have washed away much of the grove floor, the intricate systems of anchoring and bracing roots are beautifully displayed. On many cliffs and steep ridges these strong roots form a sort of natural ladder, well known to the natives and woodsmen, who utilize them in ascending or descending the slopes. In many situations ascent would be well-nigh impossible were it not for these tough, firmly anchored, exposed roots.

Lianas of various species establish themselves in the tapestry groves, and in some places become so luxuriant as to form almost impenetrable hanging jungles. Conspicuous among these vines are species of *Freycinetia*, *Dicranopteris*, *Smilax*, *Dioscorea*, *Alyxia*, *Ipomoea*, *Convolvulus*, etc. The liana formations are best developed at the lower levels; above 2000 ft. the groves are practically free from vines, which are replaced by the dense soggy moss formations.

The tapestry groves, owing to the hygrophytic environment, are usually heavily clad with thick layers of epiphytic lichens, mosses, filmy ferns, and liverworts. These layers, on the smaller branches and saplings, are often 4–8 inches in radius. The outer layer alone is green and living; the under layers, of dead vegetable material, are saturated with rain water, and may be wrung out like a wet sponge. This moss covering is best developed at the higher altitudes (1800–4000 ft.), where the annual precipitation is 100–400 inches. These upper tapestry groves are swathed in fog and rain during most of the year, and comprise a range of woody species different from that of the lower groves.

Landslides are perpetual enemies of the hanging groves. They cut short the lives of the trees which they undermine, and expose fresh rock surfaces to soil-making and revegetation. The landslides vary in width from 6 to 60 ft., and in length from 25 to 1000 ft. Owing to the slow rate of reproduction in the rain forest species, and the inhospitable climatic and soil conditions for seedlings, these rents in the tapestry are slow healing. Commonly various grasses and such ferns as *Dicranopteris* and *Sadleria* are the first invaders, followed by herbaceous-perennial seed plants (*Dianella*, *Coreopsis*) and shrubs. The arborescent species come last, and very slowly.

The two great activities of subsidence and erosion are gradually but inexorably reducing the areas occupied by the tapestry groves. The base-leveling action of erosion tends to flatten all slopes. The immeasurably slow subsidence of the entire archipelago has shrunk the original heights of the mountains. Thus, from the historical viewpoint, tapestry groves represent a transient ecological phenomena. At present it is possible to find every stage, from steep walls covered with luxuriant endemic woody tapestry, to flattened earthy hills, clad only with foreign grasses, and ranged by cattle.

The tapestry groves are of large economic value as earth protectors and water conservators. Their scenic beauty alone would amply warrant their stringent protection. As water sheds they are of much local significance. They comprise one of Hawaii's most distinctive and lovely natural assets.

HONOLULU, HAWAII

STATOCYTES OF THE WHEAT HAULM

T. L. PRANKERD

(WITH FOUR FIGURES)

The plant statocyte is a cell containing a body or bodies, the statoliths, free to move within it under the force of gravity (**1, 5**). In the mature wheat haulm, the statocytes are entirely confined to the "nodes"[1] or swellings of the leaf sheaths just above their attachment to the stem. Here they occupy more than half the total bulk, forming a definite and continuous tissue, which I have previously termed statenchyma (**5**).

Fig. 1 makes the anatomy in this region clear. The swollen leaf sheath is bordered within and without by an epidermis succeeded by a few layers of collenchyma of the type described by HABERLANDT as lamellar (**2**, p. 156). Between these layers the fibrovascular strands, consisting mainly of slightly lignified fibers, are arranged in an irregular ring, varied occasionally by smaller strands of similar fibers unaccompanied by, or surrounding a trace only of vascular tissue. The whole, or nearly the whole of the ground tissue is transformed into statenchyma, more highly differentiated than usual, since the statoliths are of two kinds. The more general type of statolith (the starch grain) is found in groups of cells occurring adaxially to the vascular strands. These sometimes form only one or two layers, but occasionally are more extensive, and even reach the internal collenchyma (fig. 1). All the other statocytes, composing by far the greater part of the ground tissue, contain crystal statoliths, and are best developed internally to, and on the flanks of the fibrovascular strands.

This position of the statenchyma within the vascular ring is unusual, although not without parallel.[2] A crystal statolith, however, is probably extremely rare, for, although expecting it, I have

[1] The term "node" is used throughout the paper in this sense.

[2] In 1911 I figured (3) the statocyte pith of *Hottonia palustris*, and since then other cases have become known to me of the conversion of the pith in whole or in part to statenchyma.

never discovered it elsewhere, notwithstanding careful search in more than a hundred plants, widely differing in habit and systematic position.

The crystal-containing statocytes are nearly twice as broad as they are long, that is, they are compressed in the axial plane. In shape they are irregularly cylindrical and hence circular in transverse section, while the longitudinal walls are generally more or less gabled (cf. fig. 3). The shape and arrangement of these cells thus allow easy extension of the tissue on bending of the node. The average diameter of the cells is about 55 μ, and the height about 30 μ. The walls are pitted, which is best seen in transverse sections showing the flat horizontal walls in surface view. Each contains a relatively large nucleus (about 18 μ diameter). In one case two nuclei were seen, although to what extent this is a general phenomenon in the wheat plant has not yet been determined (cf. **4**, note at end). The crystals usually occur singly in the cells, and when there are several this is probably due in some cases to fracture. They apparently belong to the tetragonal system (10 μ diameter), and occur as prisms, pyramids, spherical aggregates, combinations of these, or in less definite forms (fig. 4). Hydrochloric acid dissolves them at once, but they are unaffected by glacial acetic acid and various stains. From these facts their chemical composition is judged to be calcium oxalate.

The amylostatocytes decrease in size as they approach the vascular tissue, and are of much smaller average diameter than the crystal statocytes (fig. 2). Each possesses a nucleus (about 10 μ diameter), and numerous starch grains occupying about half the volume of the cell. The grains are simple, spherical, and about 5 μ in diameter. Movable crystals may also occur in these cells.

Search has been made for starch and crystals in other parts of the mature wheat plant. The latter occur in the pith of the stem, but are not free to move; and, except of course in the grain, only traces of imbedded starch have occasionally been found. Preliminary work on the seedling and young plant indicates that statolith starch exists throughout its life and appears in the same locality, that is, it is constant in time and space, while imbedded

starch is neither. The latter naturally tends to disappear from all parts while the grain is filling, and it is therefore a fact to be noted that the statolith starch is unaffected by this drain on the stored food material, and therefore cannot be regarded as primarily nutritive in function.

Both DARWIN and HABERLANDT have referred to the "falling time" (**1**, p. 771), and "period of migration" (**2**, p. 598) of statoliths, but I am not aware of any work on the *rate* of travel other than my own, which is not yet published in full (**6**). The unique feature of the wheat plant in possessing two kinds of statoliths, together with its extreme economic importance, perhaps justify a separate statement at the present time. Experimental work has demonstrated the fact that the rate of travel of the crystal is much greater than that of the starch grain, for the latter falls at about 120 μ per hour, while the rate of the former is nearer 600 μ.

The rate of the starch grain approximates to that obtained for the movable starch grains in the inflorescence axis of *Lupinus*, and is probably very average, but 600 μ per hour is about three times as great as that of any statolith known to me.

The actual time taken for the crystal to travel from one side of the cell to the other is probably under 5 minutes, and the same period for the starch grain varies with the diameter of its statocyte, but averages about 15 minutes. In nature, however, since the statocyte could never be displaced more than 90° from the vertical, the statolith would never traverse the whole diameter of the cell, but some distance less than this, and hence would reach its new position in a period of time less than that stated.

If the impact of the falling body on the living protoplasm lining the cell is a means of perception by the plant of the direction of gravity (**1**, **2**), it is the latter period which is of biological importance. It then becomes interesting to note that this period is the shortest on record. The wheat is capable of bending at the nodes in order to bring the haulm into a vertical position should it be displaced; and it is an obvious saving of energy in the transmission of stimulus that these organs should be at the same time both sensory and motor, that is, capable of perceiving and also of acting upon the appropriate stimulus.

The recognition of the node as indeed a definite sense organ of gravity perception on the part of the wheat plant readily accounts for the presence of starch in this region when the ear is ripe, which otherwise seems difficult of explanation.

I would further suggest the possibility that in the course of evolution the wheat plant may be substituting a body, metabolically harmful, but heavier and therefore quicker and better as a

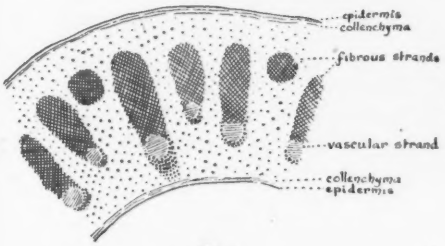

FIG. 1

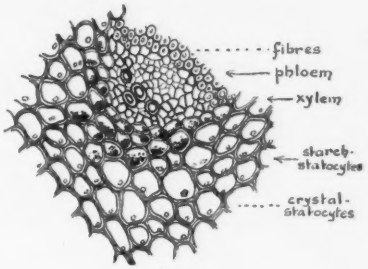

FIG. 2

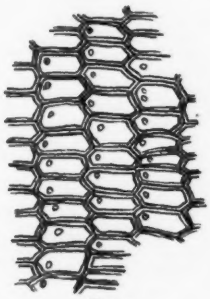

FIG. 3

FIG. 4

FIGS. 1–4.—Fig. 1, part of transverse section (diagrammatic) across node of wheat stem, showing position of statenchyma: heavily dotted line, amylostatenchyma; lightly dotted line, crystal statenchyma; ×20; fig. 2, portion of fig. 1 enlarged to show structure; ×70; fig. 3, portion of crystal statenchyma in longitudinal section; ×140; fig. 4, various forms of crystal statoliths; ×620.

statolith, for the usual starch grain, which is required as nutriment for the ear. If this be true for grasses in general, it may be one of the many subtleties of structure that have contributed to the extraordinary success of the group. I am not without hope that future work may not only establish the nodes of the wheat plant

as sense organs, but may even show that they have some bearing, even if remote, on such a practical problem as the lodging of crops.

Summary

1. The wheat haulm possesses two types of statocyte: (1) the smaller containing movable starch grains, (2) the larger with one movable crystal of calcium oxalate. Both occur only in the nodes.

2. The rate of fall of the crystal is much greater, and the period of migration considerably less than the corresponding quantities for the starch grains.

3. It is suggested that the nodes of the wheat are definite sense organs, showing a high degree of evolutionary development, and that future study of the reaction to gravity of the plant should take them into account.

Part of this investigation was carried out in the field and laboratory at Rothamsted Experimental Station, and I gratefully acknowledge the kindness of Dr. E. J. RUSSELL and members of his staff in affording me every facility while working there.

UNIVERSITY COLLEGE
READING, ENGLAND

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BRIEFER ARTICLES

RELATION OF FLAX TO VARYING AMOUNTS OF LIGHT

Certain features of a plant's metabolism take place in sunlight or diffuse daylight, while other changes go on during the period of darkness. In this connection the question arises, Is the amount of light (measured in duration, but not in intensity) received by a plant at any part of the earth's surface ever so prolonged as to serve as a check to the plant's growth? In other words, if the duration of the periods of darkness and light were approximately equal, would the plant make as much growth as in those cases where the light period is greatly in excess of the darkness period? In other words, does the prolonged exposure of a plant to light in a more northern latitude compensate to a considerable extent for the loss in temperature occasioned by distance from the equator? As an instance of this difference, Fort Simpson in latitude 62° N. has, between May 1 and August 31, 342 hours of daylight in excess of that received at Ottawa in latitude 45.5° N. A similar condition as regards light holds good on the higher slopes of mountains.

PFEFFER, in his *Physiology of Plants* (Engl. transl., **2**: p. 98) writes as follows:

> Plants are able to grow when continuously illuminated both in the polar regions and under artificial conditions, but the future must show whether all plants grow normally under light of constant intensity. For various reasons the same total quantity of light will not produce the same physiological effects when spread over the entire twenty-four hours, as when restricted to twelve hours of the day, or an even shorter period.

To determine the effect of shading plants during a short period each day at the time of year when the sun is longest above the horizon, certain experiments were made in 1916 at Ottawa, and repeated again during 1918. *Linum usitatissimum* was chosen, for the reason that it is shallow rooting, and has little tendency to branch when sown moderately thick, both of which are important considerations when plants have to be grown in pots.

The procedure followed in 1916 differed considerably from that of 1918, and will be described first. Four pots, each being 10 inches in diameter, were filled with the same kind of soil and were sunk in the

open ground up to the brim. A bell jar of about the same diameter as the pots was covered with brown paper and was placed over one of the pots for a certain time during the morning and over another during the afternoon, the exact duration of shading being noted in each case. The other two pots were left as checks. Care was taken to place the bell jar over the plants as far as possible during the time when no rain was falling, as the presence of additional moisture in some of the pots would have caused a disturbing factor in estimating the results. The temperature inside the bell jar was not noted, but there is no reason to believe that it was so different as to have any marked effect.

The pots were labeled *A*, *B*, *C*, and *D;* of these *A* and *C* were shaded, while *B* and *D* were the check pots. The seeds were sown in the pots on June 13, 1916. On June 26, when the first leaf in succession to the cotyledons had developed, 80 seedlings were left in each pot; the others in excess of this number were pulled up and thrown away.

Pots *A* and *C* were shaded on 11 days, beginning with June 26 and ending with July 10, the total duration of darkening being 28 hours and 23 minutes, in the case of pot *A;* and 28 hours and 28 minutes in pot *C*, *A* being shaded before midday and *C* in the afternoon.

On July 11 the number of plants in each pot was 64 in *A*, 68 in *B*, 78 in *C*, and 63 in *D*. On this date five of the tallest plants in each pot were pulled up, measured, and weighed, after shaking the earth from the roots. The average length and weight per plant in each lot were as follows:

Pot	Length	Weight
A (darkened)	109.2 mm.	122 mg.
B	112.4	125
C (darkened)	111.2	121
D	125.8	212

From July 12 to 20 inclusive, pots *A* and *C* were again shaded daily, except on the 16th, and the total period of darkening was 17 hours and 1 minute. On July 22 the 10 tallest plants were selected from each pot, measured, and weighed, with the following results per plant:

Pot	Length	Weight
A (darkened)	206.5 mm.	478 mg.
B	238.2	572
C (darkened)	183.5	430
D	256.5	936

On July 31 the first flowers were opening in pots *B* and *D*, while the first flower opened in pot *A* on August 2, and in pot *C* on August 4.

On August 10 ten of the tallest plants remaining in each pot were pulled up and weighed, with the following average results per plant:

Pot	Weight
A (darkened)	852 mg.
B	1160
C (darkened)	822
D	1712

These were the last observations made during 1916; no opportunity occurred to continue the work in 1917. In 1918 four 10-inch pots were again used, those labeled *A* and *C* being darkened, while *B* and *D* remained uncovered. As pots *A* and *B* were sown and examined on different dates from *C* and *D*, the data for each pair will be given separately. In both sets the pots were darkened during the morning only; on two out of every three days on which the plants were shaded the sun was shining at the time.

Pots *A* and *B* were sown with flax on May 7. On June 12, 29 of the tallest plants were left in each pot, the others being removed. Pot *A* was darkened altogether 34 hours and 53 minutes on 15 days, from June 12 to 29. On July 2 nine plants were in flower in each pot, and seeds were ripe in each on July 25. On July 27 all the plants were pulled up, measured, and weighed with the following results:

Pot	Average length	Average weight	Average number of capsules per plant
A (darkened)	514.6 mm.	1136 mg.	4.6
B	526.0	1236	5.5

Pots *C* and *D* were sown on June 8. On July 4, 36 plants were left in each pot. Pot *C* was darkened for 43 hours and 30 minutes on 18 days, from July 4 to 25. On July 25 two plants were in flower in *C* and six in *D*, while in both the first seeds were ripe on August 15. On this date the ten best plants in each pot were pulled up, measured, and weighed. The results are as follows:

Pot	Average length	Average weight	Average number of capsules per plant
C (darkened)	431.5 mm.	1248 mg.	5.0
D	530.5	2397	6.5

Summary and conclusions

1. Flax plants were raised in 10-inch pots placed in the open and sunk in the ground up to the brim.

2. From certain pots the light was excluded for 2–2.5 hours per day during periods of 11–19 days in all.

3. The shading of the plants took place between June 12 and July 25, and occurred at or near the time of year when the amount of daylight was greatest.

4. Tests were made on the shaded and unshaded plants as regards (1) average height, (2) average weight, and (3) average number of capsules produced. In every case the unshaded plants gave a higher figure.

5. As stems grow in length at a more rapid rate in darkness than in light, it might have been expected that the average height of the darkened plants would at least have equaled that of the unshaded ones, but the contrary was the case.—J. ADAMS, *Central Experimental Farm, Ottawa, Canada.*

PIER ANDREA SACCARDO

Dr. PIER ANDREA SACCARDO, who died February 12, 1920, was born at Treviso, Italy, in 1845. At the age of 21 he became connected with the Botanic Garden in Padua, where he remained until his death, first as Assistant Director, then as Director (1878) and Professor of Botany in the Royal University of Padua. He gave especial attention to Fungi, and contributed many papers to mycological literature. Among them were *Fungi Veneti novi vel critici*, series I–XII (1873–1882), and *Notae Mycologicae*, series I–XX (1890–1916). In the latter were included descriptions of new species from various regions of North America and from South America. He also published *Fungi Italici autographice delineati* (pls. 1–1280), and issued a set of *exsiccati* under the title *Mycothecae venetae* (cent. I–XI), and was editor and principal contributor to the mycological journal *Michelia*.

When SACCARDO began his labors in mycology, the general works of PERSOON and of FRIES had become antiquated. New systems of classification had been proposed, and descriptions of new genera and species had appeared in publications treating of limited regions and scattered in periodical literature and society transactions. The fame of SACCARDO will rest most largely on the measures he took to meet this situation. He projected and carried through the publication, in one series, of descriptions of all known species of Fungi based in the beginning on 600 separate publications. The first volume of this work (*Sylloge Fungorum omnium hucusque cognitorum*) appeared in 1882, and the task was finished when vol. VIII appeared at the end of 1889, the volumes

averaging about 600 pages each and being provided with keys and adequate indexes to genera, species, and hosts. With the publication of vol. IV he found it necessary to have assistance, and in subsequent volumes CUBONI, MANCINI, BERLESE, DETONI, ED. FISCHER, PAOLETTI, and TREVISAN collaborated. To carry out this plan, however, there was first of all necessary a general system of classification, and the one which he devised and used in the *Sylloge* has been followed in practically all subsequent work in mycology. That it was a natural and perfectly satisfactory one no one would affirm, but it was perhaps the best that could be framed in the present state of knowledge of the Fungi, and will probably remain in use as a practical, workable system until such time as a more natural one can be devised.

The completion of this work did not end SACCARDO's labors. Mycological activity, stimulated by the publication of the *Sylloge*, was such that it quickly became necessary to issue supplementary volumes, the first of which appeared in 1891, the last, a work of 1600 pages, bringing the matter up to the end of 1910, in 1913. P. SYDOW, MUSSAT, D. SACCARDO, TRAVERSO, and TROTTER were collaborators in the preparation of these supplementary volumes, which included 2 volumes (2467 pages) of index to published figures of Fungi. The 22 volumes of the *Sylloge Fungorum* constitute the working handbook of every mycologist.

SACCARDO was a good correspondent and a gracious one. Material was sent to him from all quarters for determination, and he became the court of last resort to many mycologists, and in this way as well as through his publications he gave impetus to the study of Fungi. The effect of his work illustrates again the fact that progress in botany, as in other sciences, is based not only on brilliant research and broad generalization, but also on a large amount of downright drudgery.—J. J. DAVIS, *University of Wisconsin, Madison, Wisconsin.*

CURRENT LITERATURE

BOOK REVIEWS

Hardwoods of Australia

Ten years ago BAKER[1] published an elaborate book on the pines of Australia. He immediately commenced work upon a companion volume dealing with the native hardwoods, and some of the material was on exhibition at the Sydney Technological Museum, of which Dr. BAKER has long been the director. The work has now been completed, and it brings great credit, not only to the author,[2] but to the Museum and Commonwealth for undertaking and financing an unusually expensive investigation.

The dominant object of the work is to make known to Australians, and to the world in general, the diversity and economic value of the Australian hardwoods. In America, and doubtless in many other countries, the popular mind has become so accustomed to mahogany as the conventional wood for pianos, victrolas, and fine furniture, that other woods, which might be stronger and more beautiful, receive scant recognition.

BAKER has had various kinds of plain and ornamental furniture, plain and carved interior furnishings, and a great variety of useful and ornamental things, from carved gavels to railway bridges, made from native woods, and has shown conclusively that Australians do not need to go outside their own country for any kind of timber. The needs of the architect, builder, engineer, cabinet-maker, and forester are kept in mind, and valuable suggestions, based upon practical experiments, form a feature of the work.

It is interesting to learn that not less than nine-tenths of the Australian trees are hardwoods. The United States and Canada have about 700 species of trees; Australia has about 500, but many of them have a wide range. The genus with the largest number of species, the greatest variety in hardness, color, and finish, as well as the widest distribution, is *Eucalyptus;* and in reforestation the genus could hardly be surpassed, for the blue gum in 24 years becomes as large as the English oak in 200 years. One figure of *Eucalyptus regnans* shows annual rings with a width of more than a centimeter. This is not cited as a record, for the author remarks that a specimen of *Sequoia sempervirens* at Reefton, New Zealand, known to be 27 years old, was "nearly 3 ft. in diameter, with some of the rings measuring an inch in width." This means that reforestation would be so rapid that it would have an immediate practical aspect. Species of *Acacia* yield extremely hard timber, some as red

[1] BAKER, RICHARD I., and SMITH, HENRY G., A research on the pines of Australia. 4to. pp. xvi+548. Sydney. Government of New South Wales. 1910.

[2] BAKER, RICHARD T., The hardwoods of Australia and their economics. 4to. pp. xvi+523. Sydney. The Government of New South Wales. 1919. £1. 5*s*.

as rosewood, some as black as ebony, while others have a lighter color. Species of *Casuarina* also yield hard wood of various colors, some looking like oak already fumed.

The hardness and weight of *Eucalyptus* timbers are due to the predominance of thick-walled fibers. In some of the extremely hard woods of the genus the vessels are almost entirely blocked by tyloses. The figure in the wood is not due to large rays, as in oaks, but to the fact that fibers and wood elements run in waves. In color, this single genus furnishes perfect imitations of maple, locust, cherry, mahogany, and rosewood; while the timber, as hard and strong as any of these, takes a magnificent polish.

The taxonomic sequence follows that of BENTHAM and HOOKER. In each case there is a systematic diagnosis, with geographical range, and a description of the timber and its uses. Local names are given in addition to the scientific names. The rank in a scale of hardness and the weight per cubic foot are also given, and some of this information is summed up in a table according to hardness: extremely hard, very hard, hard, and moderate. In most cases photomicrographs illustrate transverse, longitudinal radial, and longitudinal tangential sections, which not only show the structure but also indicate the strength, hardness, and weight of the wood.

An unusual feature is a table of combustibility. Since wood in Australia is used to a considerable extent in railroad bridges and in shipbuilding, resistance to fire is a very desirable quality. By means of a "xylopyre" the time required to burn up a piece of wood of a definite size was determined with great accuracy. These tests show that many of the Australian woods are remarkably resistant to fire. In this quality *Eucalyptus Fletcheri* easily heads the list, with 19 minutes required to burn the test piece; next comes *Syncarpia laurifolia*, with 12 minutes; then *Casuarina torulosa*, with 8 minutes; followed by many species of *Eucalyptus* ranging from 7 minutes down to 3 minutes. The significance is evident when we note that in the same test our *Pseudotsuga Douglasii* has a time limit of 4 minutes, *Quercus alba* 3 minutes, *Juglans* sp., *Fagus sylvatica*, and *Sequoia sempervirens* less than 3 minutes.

A striking feature of the work, and one most likely to give it immediate practical importance, is a series of 126 magnificent plates in color, illustrating the natural appearance of the wood. These plates, together with the photographs of various articles, inside furnishings, buildings, etc., prove the variety and value of the Australian hardwoods.

The timely warnings, calling attention to the desirability of sane lumbering methods and the necessity for reforestation, should be heeded while the timber supply is still abundant.—C. J. CHAMBERLAIN.

NOTES FOR STUDENTS

Form and growth of trees.—In 1913 the Schnyder von Wartensee Foundation opened a prize competition of three years' duration "to stimulate new investigations upon the growth in thickness of trees." First prizes

subsequently were awarded to ARNOLD ENGLER and PAUL JACCARD, professors in the Federal Polytechnical School in Zurich.

ENGLER[3] concerns himself with the effects of geotropic and heliotropic stimuli upon the form and structure of arborescent plants. He is of the opinion that old stout stems and branches of dicotyledons may develop marked geotropic and heliotropic curvatures, but considers that, in the case of the Coniferae, heliotropic bending is confined to the younger, more pliable portions of the stem. He devotes considerable attention to the study of the form and growth of broad-leaved trees on steep slopes, and concludes that the terminal shoots, particularly during the earlier stages in the ontogenetic development of the trees, tend to bend downhill toward more intensive illumination upon that side. During subsequent growth these curvatures are more or less completely neutralized by bending in the opposite direction in response to geotropic stimuli. His numerous stem analyses show that trees growing on steep slopes may be eccentric on the uphill side, the downhill side, or vary in their eccentricity at succeeding heights in the stem. Accelerated growth upon the uphill side is assumed to be due to geotropic stimuli, regardless of whether the stem is concave or convex, and eccentricity on the downhill side, as in Coniferae, to longitudinal compression upon the cambial layer. He reaches similar conclusions in regard to the eccentricities of stems and branches of trees growing upon level ground. In other words, accelerated growth upon the upper sides of stems or branches is geotropic, whereas that upon the under sides is due to longitudinal compression. The geotropic stimulus ceases to act only when the terminal shoot occupies a vertical position. Different parts of a tree may react differently toward light and gravitational forces. Thus in the younger (higher) portions of a stem heliotropic frequently overshadow geotropic stimuli, so that geotropic curvature and eccentricity are confined to the base of the stem. In dicotyledons the influence of gravity usually exceeds that of longitudinal compression, and accelerated growth of the under sides of stems and branches is found only where it is not inhibited by negative geotropism. Lateral eccentricity occurs when these two factors, working in opposition, neutralize each other. Longitudinal compression affects the volume of secondary xylem but not its structure. In ring-porous dicotyledons, "geotropic wood" is characterized by wider vessels and a greater proportion of summer wood; but in diffuse porous species, the wood of the upper and lower sides of stems and branches is of the same general type.

As evidence in favor of these views, ENGLER cites the crooked or curved stems of trees growing under peculiar environmental conditions; for example, on steep slopes, displaced from the normal vertical position, in unilateral

[3] Tropismen und exzentrisches Dickenwachstum der Bäume; Ein Beitrag zur Physiologie und Morphologie der Holzgewächse. Schr. Stift. Schnyder von Wartensee Zürich **21**:1–106. *figs.* 1–30. 1918.

illumination, etc.; such data as may be secured by critical field observations, detailed stem analyses, and a careful study of the past environmental history of the plants. Thus the method of attacking the problem consists in showing that variations in form are closely correlated in each case with variations in illumination, gravitational, or mechanical forces. Since it places a premium upon circumstantial evidence and deductive reasoning, its ultimate success is dependent upon the number of concordant facts that can be advanced in its favor. Although ENGLER's data indicate that bending actually occurs in old stems, they do not demonstrate in all cases that the curvatures are due necessarily to particular stimuli. For example, in tall dense forests, the sudden curvatures of trees toward gaps made by thinnings may be heliotropic; but it is also conceivable that they may be due to a lack of rigidity in tall (13–18 m.) very slender (8–13 cm.) trees. The reviewer has seen thinnings in lodgepole pine forests in which the crowns of tall unsupported trees have bent over until they touched the ground. Furthermore, if bending occurs in response to heliotropic stimuli and is produced by the activity of living cells (parenchyma) in the sapwood, as ENGLER supposes, the structure of the stem must be considerably modified. No conclusive evidence is presented to indicate that such modifications actually have taken place.

In the second of the prize essays, JACCARD[4] attacks the problem of the form and growth of trees from an entirely different angle. The first twelve chapters of his memoir are devoted to a criticism of the SCHWENDENER-METZGER hypothesis, which holds that the form of trees is determined largely by mechanical factors (wind and gravity), and to an exposition of his own theory that the "clear length" of the stem is, at successive heights, a shaft of equal water-conducting capacity. Inasmuch as this portion of the memoir is largely a recapitulation of former papers, which have been reviewed by GROSSENBACHER[5] and others, it may be passed over without further comment. The three succeeding chapters (pp. 101–169) are concerned with interesting experiments, designed to test the effects of mechanical, geotropic, and heliotropic stimuli and various types of girdling upon the form and anatomical structure of conifers and dicotyledons. A large number of young stems and branches were subjected to various types of flexure (sustained or intermittent). Their subsequent growth, form, and structure were found to vary, depending upon the intensity and duration of the stimuli. Thus if the stem of an erect conifer is bent alternately to the north and south, no "redwood" is formed unless the stem is allowed to remain in each posture for a certain period

[4] JACCARD, PAUL, Nouvelles recherches sur l'accroissement en épaisseur des arbres: Essai d'une théorie physiologique de leur croissance concentrique et excentrique. Pub. Foundation Schnyder von Wartensee Zürich **23**: i–xii+1–200. *pls. 1–32. figs. 1–75.* 1919.

[5] GROSSENBACHER, J. G., The periodicity and distribution of radial growth in trees and their relation to the development of "annual" rings. Trans. Wis. Acad. Sci. **18**: part 1. 1915.

of time. Again, a slight curvature may accelerate the growth on the upper side of a dicotyledonous stem, whereas a more pronounced bend may produce eccentricity upon the under side or inhibit the growth of both the upper and under sides and lead to lateral eccentricity.

In the fifth and concluding section of the volume, JACCARD elaborates the following hypothesis: "The morphological characters common to all trees are determined (1) by the polarity of their organs, that is to say, by their tendency to grow most rapidly in a vertical direction, and (2) by the modifications which the exigencies of nutrition and the action of external forces (gravity, heat, light) impress upon this polarity. These modifications manifest themselves through the osmotic force of cells which engenders, on the one hand, two circulatory currents (the ascending sap and descending current of elaborated substances), and, on the other hand, mechanical strains and stresses (pressure of turgescence) capable of influencing the form of cells. . . . . In general, such variations in gross form and anatomical structure, as may be observed at different levels in the concentric, vertical axes of trees, are determined by the physical conditions of the transpiration stream and the flow of elaborated sap. On the contrary, the anatomical differentiation and variations in transverse sections, which are concomitants of the eccentric growth of inclined or horizontal branches, are due to mechanical forces engendered by the unequally rapid growth of the antagonistic sides of these organs, under the asymmetrical influence of gravity and light."

Although the author is justified in contending that the problem of the growth and form of stems and branches should be attacked from the point of view of fundamental physiological phenomena, and in rejecting teleological conclusions as unscientific, he extends his own generalizations much farther than is warranted by his experimental data. When one considers how little is actually known about the "ascent of sap," the growth and activities of the cambium and its derivative tissues, the distribution of food substances and osmotic pressures, and, in general, concerning transpiration, metabolism, and translocation and their interactivities in arborescent plants, one is inclined to question whether there are available at present sufficient reliable data to form the basis for such a comprehensive hypothesis as is formulated by the author.—I. W. BAILEY.

Factors of fruitfulness.—A contribution by WIGGINS[6] covers investigations for 5 years, chiefly upon trees that were 8 years old at the beginning of the experiment in 1913. Attention was centered upon the individual fruiting branch "in an effort to determine the effect of certain conditions and practices upon the development and performance of the individual fruit spur."

The data for the performance of the individual spurs were obtained from 8-year-old Rome, Gano, Winesap, Grimes, York, and Jonathan. The first selection was made of fruiting spurs, but after that a blossoming spur was

[6] WIGGINS, C. C., Mo. Exp. Sta. Research Bull. no. 32. 1–60. 1918.

considered to be a fruiting spur for the season in which it bloomed. It might be questioned whether the author was justified in making such an assumption.

Jonathan, Winesap, and Grimes were found to produce a fair amount of bloom each year, but with no exceedingly productive seasons; while Rome, York, and Gano were found to have a very high percentage of bloom one season and a comparatively low one the next. Winesap and Jonathan, in the order named, were able to develop blossoms in successive seasons on the same spur in a much greater proportion than the other varieties. The difference between alternating and non-alternating varieties seems to be due to the ability of the spurs of the regular bearing kinds to blossom two years in succession. The most effective fruiting age for the spurs, irrespective of the type of bearing, appeared to be from 3 to 7 years.

Determinations of the relative amounts of food reserve in the fruit spurs were made by finding the lowering of the freezing point in the spur sap by means of a Beckman apparatus. Only relative proportions of reserves were indicated by the lowering of the freezing point, and starch not at all. It was found that sap from the bearing spurs had a slightly higher concentration during a considerable portion of the year than sap from non-bearing spurs. It must be remembered, however, that the method of analysis gave no indication of the amount of starch that might have been present. It was found that during the latter part of June and early July there was a sudden drop in concentration of sap, both in fruiting spurs and non-fruiting spurs, and at that time both kinds of spurs reached a similar degree of concentration. The author concluded also that little difference in concentration of the cell sap could be attributed to soil conditions or to the number of fruits being produced upon a spur.

Chemical analysis of the spurs of Yellow Transparent were made in order to ascertain the amounts of sugars and starch stored. It was found, in the majority of cases, that there was a slightly greater amount of sugar, both reducing and total, in the non-bearing spurs. The starch content of the non-bearing spurs did not average quite so high as that of the bearing spurs, but there was considerable variation in these results. Inasmuch as the determinations made were comparatively few in number (22) and covered only the period from late October to April, no conclusions were drawn. A determination of nitrogen would have made this work much more valuable.

It was found that non-bearing spurs had a larger total leaf area than bearing spurs, and that the difference was due more to the number of leaves than to the size of the individual leaves.

The effects of girdling upon the concentration of cell sap were determined by noting the depression of the freezing point. The sap of all parts above the girdle was found to have an increased concentration, and the sap of all parts below the girdle a decreased density when compared with sap from corresponding parts of similar but ungirdled trees. The greatest effect was observed upon the sap of the trunk, and the difference became less as the distance from

the girdle increased; consequently the leaves and twigs at the periphery of the tree, where the majority of the fruit buds were formed, did not show such a great variation.

The experiment to determine the effect of fertilizers upon fruitfulness was started with 1-year-old Rome on Paradise stock. The trees were planted in separate large wooden tubs, half of them filled with Missouri River sand and half with loess soil. The fertilizers were applied just as growth was beginning in the spring. It was found that nitrogen was a very decisive factor in the growth of the tree, the development of fruiting wood, and the formation of blossoms. Phosphorus and potassium, either singly or in combination, had no apparent effects.

The effect of various systems of soil management was noted upon the concentration of the cell sap. There were 5 different cultural plots: clean cultivation with soy beans or cow peas planted in June; successive crops of corn; seeded to red clover in alternate years; successive cropping of alfalfa; and permanent timothy sod. "These experiments showed conclusively that tillage methods materially affected the sap density of the twigs of the apple tree." The plots ranked in sap concentration of the twigs as follows: alfalfa; timothy and blue grass sod; clover; corn; and clean cultivation with legume cover planted in June. There was very little difference between the clover and corn plots. The trees in the most intensively cultivated areas were considerably the largest.

A group of 64 one-year-old Delicious trees were used to study the effect of pruning methods upon the formation of fruiting parts. During the first 3 years the trees headed at 2 feet made a greater amount of twig growth and produced a larger number of short branches or potential fruiting wood than did the trees headed at 5 feet. Each month a separate 5- to 6-year-old Jonathan tree was subjected to etherization. Very little effect was observed upon the concentration of the sap of the spurs or of the leaves, and the small difference noted appeared to be only temporary. A rather extensive bibliography accompanies the article.—H. W. RICHEY.

Phylogeny of seed plants.—At the St. Louis meeting of the American Association, the botanical program included a symposium on the phylogeny of seed plants. The three invitation papers have just been published. The three investigators, working upon different phases of the problem, have shown tendencies in the evolution of the groups with which they are concerned; and while the phylogeny of seed plants still represents a great field for exploration, some results have been obtained, and the problem has been advanced a little toward the distant solution.

BUCHHOLZ[7] has made a comprehensive survey of the development of the embryo and polyembryony in the conifers, much of the subject-matter being

[7] BUCHHOLZ, J. T., Embryo development and polyembryony in relation to the phylogeny of conifers. Amer. Jour. Bot. 7:125–145. 1920.

his own contribution. He concludes that the apical cell in early embryogeny, cleavage polyembryony, rosette embryos, rosette cells, and the direct organization of embryo initials from free nuclei of the proembryo are primitive features; while the organization of embryo initials after walls form in the proembryo, a proembryo that fills the entire egg with cells, the archegonium complex, the embryo cap, and the return to simple polyembrony are advanced or specialized features. A study of polyembryony throughout the groups shows that cleavage polyembryony tends to become more or less eliminated in passing from the lower to the higher genera, and consequently the conifers must have been derived from ferns with cleavage polyembryony.

CHAMBERLAIN,[8] in dealing with the Cycads, considered two questions: "What has been their origin?" and "Have they left any progeny?" From a study of the comparative morphology of the entire Cycadophyte phylum, from the Paleozoic to the present time, he concludes that the Cycads could not have come from any Mesozoic forms of the *Cycadeoidea* type, or from any known forms of the Lower Mesozoic. If they have come from any of the Bennettitales, they have come from forms so nearly like the Cycadofilicales, to which the Bennettitales themselves owe their origin, that whether the Cycads are an early branch from the Bennettitales, or have come from the Cycadofilicales directly, can be answered only by fossils still to be discovered and studied.

The second question, so far as the living Cycads are concerned, is answered positively in the negative. The groups of living seed plants are considered separately, and the conclusion reached that the Cycads are not responsible for any of them. This conclusion was emphasized by some facts indicating that the Coniferophytes and Angiosperms have a more reasonable origin in the Ferns or Lycopods. Stress is laid upon the fact that the extinct forms which have been preserved are mostly woody, especially in the Mesozoic. Have herbaceous Gymnosperms been lost which may have given rise to herbaceous Angiosperms? Could such Angiosperms have given rise to the woody Angiosperms which became prominent in the Cretaceous? It is difficult to derive these Angiosperms from any known woody Gymnosperms.

The general conclusion is that the Cycadophytes have come from Ferns, and that they have not left any progeny outside of the Cycadophyte line.

WIELAND[9] deals first with the distribution of seed plants, almost exclusively with fossil seed plants, and then discusses relationships. In living plants, only lateral distribution is considered, but in fossil forms both lateral and vertical distribution must be studied. The vertical distribution, in most cases, is better known than the lateral, and the period of extinction is more determinable than the first appearance. The Carboniferous flora is better

[8] CHAMBERLAIN, C. J., The living Cycads and the phylogeny of seed plants. Amer. Jour. Bot. 7:146–153. 1920.

[9] WIELAND, G. R., Distribution and relationships of the Cycadeoids. Amer. Jour. Bot. 7:154–171. 1920.

known because the economic value of coal has uncovered immense areas; while the Permian, Rhaetic, or Middle Triassic have depended upon the enthusiasm of about a dozen scientists. The flora of these horizons is probably as abundant and varied as that of the Carboniferous, but not so available.

In going back through the geological horizons, there is a gradual merging of Coniferophyte, Cycadophyte, and Ginkgophyte foliage toward seed-bearing "quasi-ferns." Also toward the early Paleozoic there seems to be some kind of contact between the early seed ferns and the older Lepidophyte types leading toward the primitive Gymnosperms. Whether well down in the Devonian some of the Lepidophytes, like the later seed ferns, may also have led into the primitive Gymnosperms is the real riddle of paleobotany, more so than the origin of Angiosperms. In almost all instances the doubtful border of Cycadeoid foliage ends in a tree forest of seed ferns, *Cordaites*, pines, araucarians, and Ginkgoes, but never in a recognizable scrub. It is stated that among the Cycadeoids will be found the lost forests and the greatest forest makers of the Mesozoic.

WIELAND suggests that from age to age great groups have come down side by side, undergoing endless change and losing apparent relationships; but almost no forms, scarcely a family, need be regarded as more ancient or more modern than any other. It is conceivable that all the antecedent types of Angiosperms are discrete separate lines leading back to the first forests of the Devonian.—J. M. C.

History of cotyledony.—BUCHHOLZ,[10] in connection with his studies of embryo development in conifers, has reached certain conclusions in reference to the primitive condition of cotyledony and its subsequent evolution. His investigations showed that in a number of conifers fusions of cotyledons occur during embryogeny, and that there is no evidence of splitting. Fusion results not merely in a reduced number of cotyledons, but often in the development of cotyledonary tubes. The conclusion is that the primitive gymnosperm embryo had numerous cotyledons; that fusions resulted in a reduced number; that dicotyledony was attained either by a fusion of cotyledons into two groups or by an extremely bilabiate development of a cotyledonary tube; and that monocotyledony is the result of a cotyledonary tube becoming "unilabiate" in its development. According to these conclusions, therefore, polycotyledony is primitive, dicotyledony is derived, and monocotyledony is the extreme expression of cotyledonary fusion.—J. M. C.

Life cycle of climbing bamboo.—SEIFRIZ[11] has published some observations on one of the climbing bamboos (*Chusquea abietifolia*) growing in Jamaica.

[10] BUCHHOLZ, J. T., Studies concerning the evolutionary status of polycotyledony. Amer. Jour. Bot. **6**:106–119. *figs. 25.* 1919.

[11] SEIFRIZ, W., The length of the life cycle of a climbing bamboo; a striking case of sexual periodicity in *Chusquea abietifolia* Griseb. Amer. Jour. Bot. **7**:83–94. *figs. 5.* 1920.

It is a species little known outside Jamaica, and is restricted there to the mountainous interior. It is one of the plants that live vegetatively for a number of years and then flower and die. *Agave americana* ("century plant") is the most commonly cited illustration of this habit. The bamboos are notable for this kind of periodicity, the number of years of vegetative activity before flowering varying widely in different forms. Apparently, when flowering occurs, most of the individuals of a region are involved, and presently all the mature plants are dead, and the ground occupied by seedlings. SEIFRIZ had an opportunity to observe the flowering condition of *Chusquea abietifolia* in 1918, and the records available showed that the previous flowering condition had occurred 33 years before. The explanation of this behavior is not available as yet, for seasonal factors controlling such long periods are very unlikely.—J. M. C.

Mosaic disease of spinach.—Investigations of JODIDI, MOULTON, and MARKLEY,[12] of the Bureau of Plant Industry, have shown that "spinach plants, especially their tops, affected with mosaic disease, have a smaller percentage of total nitrate, acid amide, mono and diamino nitrogen, but a somewhat larger percentage of ammonia than normal plants, nitrous acid being present in diseased plants only. This is due to the fact that denitrification takes place whereby nitrates are reduced to nitrites which, reacting on various nitrogenous compounds present in the spinach, bring about elimination of nitrogen in a free state, involving also loss of nitrogen in the form of ammonia."

It will be very interesting to know how generally in physiological diseases of plants and in viris and other disorders denitrification is involved.[13]—WM. CROCKER.

Leaching of nitrates.—Working with uncropped and unmanured soils RUSSELL and RICHARDS[14] conclude that "the nitrate in drainage water accounts for practically all the nitrogen lost from the soil. The uncertainty attaching to the estimated figures and to the actual amount of new nitrogen in the rainfall deprives the balance sheet of precision, but there is no room for much fixation or loss of gaseous nitrogen. The chief, if not the sole action, in this soil when there is no manure, crop residues, or fresh supply of organic matter, is the production of nitrate. It is in these circumstances that the nitrogen cycle is seen at its simplest. We know from other Rothamsted experiments that the cycle becomes more complex when organic matter is added to the soil, both fixation and loss of nitrogen being then liable to occur."—WM. CROCKER.

[12] JODIDI, S. L., MOULTON, S. C., and MARKLEY, K. S., The mosaic disease of spinach as characterized by its nitrogen constituents. Jour. Am. Chem. Soc. **42**:1061–1070. 1920.

[13] BOT. GAZ. **65**:199–200. 1918.

[14] RUSSELL, E. J., and RICHARDS, E. H., The washing out of nitrates by drainage water from uncropped and unmanured land. Jour. Agric. Sci. **10**:22–43. 1919.

Contraction of roots.—Miss CHURCH[15] has studied the contraction of roots, and while she thinks some of RIMBACH's conclusions were not justified by his facts, she thinks the following can be accepted: "(1) roots do shorten; (2) the parenchymous tissues of the root are the seat of activity; (3) the cork and the vascular trace are passive; (4) the cork is ultimately crushed; (5) there is a region where one can see wrinkling and measure shortening, a second region where no wrinklings are visible yet one can measure shortening, and an unchanged region (RIMBACH); in dicotyledons the trace becomes visibly curved inward and outward in a wavy fashion, while in monocotyledons the vascular bundles remain practically straight (DEVRIES)."—WM. CROCKER.

Energy of biological processes.—LINHART[16], in a preliminary paper, has called attention to the almost neglected field of study of the energy relations in biological processes. By employing similar methods to those recently used in attempts to base chemical reactions on thermodynamic principles, LINHART hopes to be able to measure the energy values of various biological processes. The heats of combustion of the nutrient materials must be known. With these data, and the entropies of the substances involved, it is possible by thermodynamic equations to compute the free energy from a reaction. The energy available to *Azotobacter* grown on mannite was thus calculated. The amount of NH_3 fixed by *Azotobacter* in consuming a certain amount of mannite was found to represent only about 1 per cent of the energy value of the mannite.—J. R. MAGNESS.

Heat treatment of seeds.—ATANASOFF and JOHNSON[17] give a preliminary report of their work on heating cereal seeds as a means of killing seed-carried parasites. They emphasize the necessity of applying this method only to high quality, well dried seeds. They could thus dispose of bacterial blight of barley and of oats. The wheat scab (*Gibberella soubinetii* and *Fusarium* spp.), primary infections only, and spot blotch of barley (*Helminthosporium sativum*) are practically eliminated by dry heat treatment. The *Helminthosporium* blotch of oats, as well as loose smut of barley and smuts of oats, were markedly reduced by such treatment. In all of these cases, of course, the germination was not materially injured.—WM. CROCKER.

Soil moisture.—KEEN[18] gives an excellent discussion of the latest literature on the mechanics of soil moisture.—WM. CROCKER.

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